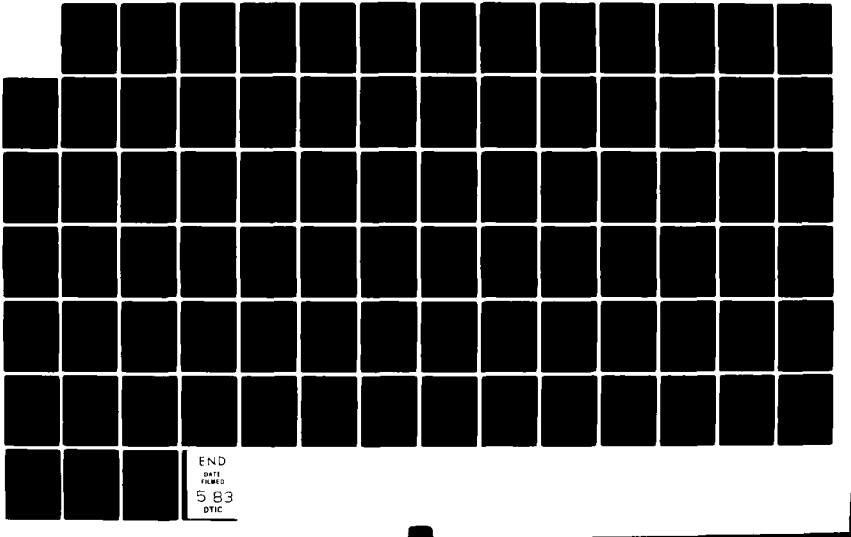
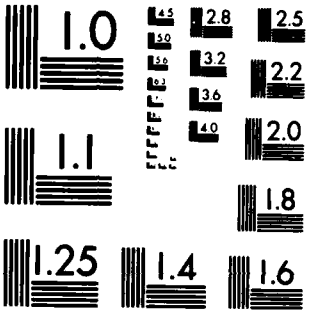
AD-A127 163 GPRIME/GGEN INTERACTIVE FINITE ELEMENT DATA GENERATOR 1/1
(U) DAVID W TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT
CENTER BETHESDA MD D R WALLACE ET AL. MAR 83
UNCLASSIFIED DTNSRDC-83/021 F/G 9/2 • NL



END
DATE FILMED
5 83
DTIC



DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Maryland 20084

GPRIME/GGEN INTERACTIVE FINITE ELEMENT DATA GENERATOR

by

Dolores R. Wallace
James M. McKee

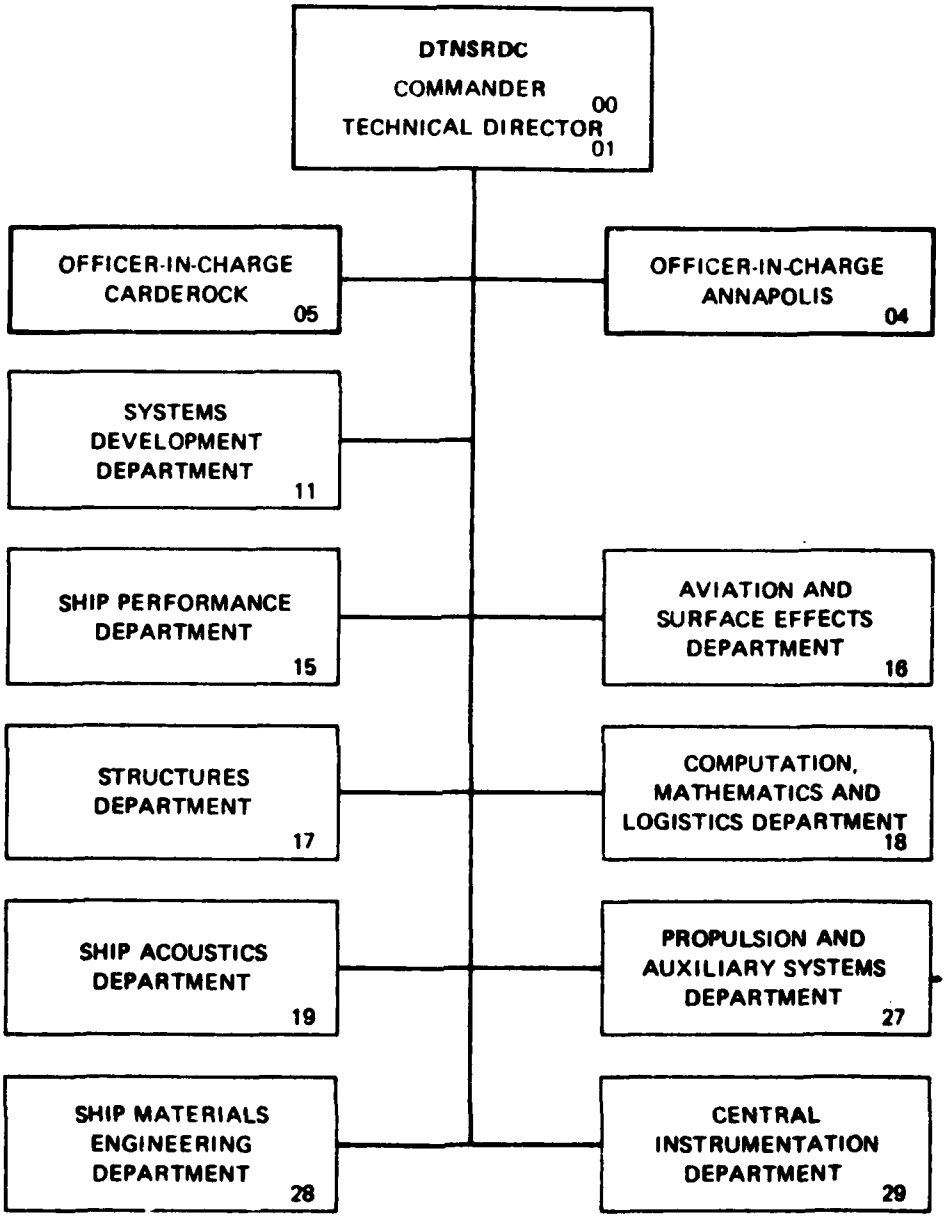
APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

COMPUTATION, MATHEMATICS AND LOGISTICS DEPARTMENT
RESEARCH AND DEVELOPMENT REPORT

March 1983

DTNSRDC-83/021

MAJOR DTNSRDC ORGANIZATIONAL COMPONENTS



UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER: DTNSRDC-83/021	2. GOVT ACCESSION NO.: AD-A127 163
	3. RECIPIENT'S CATALOG NUMBER:
4. TITLE (and Subtitle): GPRIME/GGEN INTERACTIVE FINITE ELEMENT DATA GENERATOR	5. TYPE OF REPORT & PERIOD COVERED: Final
	6. PERFORMING ORG. REPORT NUMBER:
7. AUTHOR(s): Dolores R. Wallace James M. McKee	8. CONTRACT OR GRANT NUMBER(s):
9. PERFORMING ORGANIZATION NAME AND ADDRESS: David W. Taylor Naval Ship Research and Development Center Bethesda, Maryland 20084	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: Program Element 62543N Task Area SF-43-411-391 Work Unit 1808-009
11. CONTROLLING OFFICE NAME AND ADDRESS: James J. Sejd Naval Sea Systems Command (05R24) Washington, D.C. 20362	12. REPORT DATE: March 1983
	13. NUMBER OF PAGES: 85
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)	15. SECURITY CLASS. (of this report): UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

GPRIME
Geometry Modeling
Computer Language
Computer Graphics
Interactive Processing
Finite Element
Structural Analysis

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The GPRIME/GGEN interactive general finite element data generator is a computer software system which generates finite-element models from GPRIME geometric descriptions of structures. GGEN permits interactive generation of two-dimensional elements with uniform or non-uniform meshes, with user options on node and element numbering. The user may create these data in large quantity with a single keyboard command, or in smaller groups or singly either by keyboard command or graphic control. Nodes and elements

(Continued on reverse side)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-LF-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

(Block 20 continued)

may be changed or deleted with either keyboard commands or cursor controls. Display features include scaling, translations, and rotations as well as selection of items to be displayed. The output file consists of grid point data coordinates and element connection data. Error messages are designed to enable the user to recover from errors and to continue the GGEN process.

The GGEN data generator is designed as an applications program using the GPRIME geometric language and language processor. GPRIME features available at any time during the GGEN modeling process include GPRIME processing of changes, print options, HELP messages, new geometry, access to existing geometry, viewing options, and restart capability.

This manual defines both the GGEN command structure and the methods of communication with GPRIME. Examples have been included to illustrate various concepts and procedures.

TABLE OF CONTENTS

	Page
LIST OF FIGURES	iv
ABSTRACT	1
ADMINISTRATIVE INFORMATION	1
INTRODUCTION TO THE GPRIME/GGEN APPROACH	1
CONVENTIONS USED IN THIS MANUAL	3
ENTERING, LEAVING AND SAVING GPRIME/GGEN	5
GGEN	5
END, QUIT	6
SAVING DATA BASES	7
COMMUNICATION BETWEEN THE GGEN AND THE GPRIME PROGRAMS	8
HELP	8
ACTIVATE	9
DEACTIVATE	11
PROCESS	11
GROUP	13
GPRIME	15
SIMPLE BULK DATA GENERATION (GENERATE)	15
CONTROLLING THE DETAILS OF BULK GENERATION (SPACING)	20
INTERACTIVE DATA GENERATION AND MODIFICATION	26
GGEN MODULE CREATE	27
GGEN MODULE EDIT	33
EDIT MODULE FUNCTIONS	37
PARTITIONING THE MODEL FOR INTERACTIVE PROCESSING (WORKSPACES)	42
WORKSPACE DISPLAY FUNCTIONS	45
WORKSPACE MAINTENANCE FUNCTIONS	47
DELETING AND CHANGING NODES AND ELEMENTS	53
DELETE, PURGE	54
RETAIN	55

Page

CONTROLLING THE DISPLAY OF THE MODEL 57

SPECIAL PURPOSE TRANSFORMATIONS (ADJUST) 59

COMMUNICATION WITH OTHER PROGRAMS (PUNCH) 60

USING A DIGITIZING BOARD WITH GGEN 61

EXPERIMENTAL GGEN MODULES 61

GGEN MODULE DHIR (EXPERIMENTAL) 62

GGEN MODULE TRM (EXPERIMENTAL) 63

GGEN MODULE TRIANGLE (UNFINISHED, EXPERIMENTAL) 63

GGEN DIFFERENCES ON OTHER COMPUTERS 64

COMPUTER TERMINAL CONTROLS 64

INITIALIZATION PROCEDURES 65

USER-COMPUTER INTERFACE 68

PHILOSOPHY: DISK VS VIRTUAL MEMORY 69

DATA MANAGEMENT 70

GGEN COMMAND INDEX 72

ACKNOWLEDGMENTS 74

REFERENCES 75

LIST OF FIGURES

1 - GPRIME and GGEN Views of the Same Surfaces 6

2 - Bulk Generation of Triangles and Quadrilaterals 16

3 - Simple Mesh Refinement with SET Function 22

4 - GGEN/EDIT Menu 34

5 - Example of STATUS Table 52

6 - DELETEd Data Marked with "X"; Removed on Redraw 53

7 - VAX Control Characters 66

ABSTRACT

The GPRIME/GGEN interactive general finite element data generator is a computer software system which generates finite-element models from GPRIME geometric descriptions of structures. GGEN permits interactive generation of two-dimensional elements with uniform or non-uniform meshes, with user options on node and element numbering. The user may create these data in large quantity with a single keyboard command, or in smaller groups or singly either by keyboard command or graphic control. Nodes and elements may be changed or deleted with either keyboard commands or cursor controls. Display features include scaling, translations, and rotations as well as selection of items to be displayed. The output file consists of grid point data coordinates and element connection data. Error messages are designed to enable the user to recover from errors and to continue the GGEN process.

The GGEN data generator is designed as an applications program using the GPRIME geometric language and language processor. GPRIME features available at any time during the GGEN modeling process include GPRIME processing of changes, print options, HELP messages, new geometry, access to existing geometry, viewing options, and restart capability.

This manual defines both the GGEN command structure and the methods of communication with GPRIME. Examples have been included to illustrate various concepts and procedures.

ADMINISTRATIVE INFORMATION

The work reported here was performed as part of Program Element 62543N, Task 15325, Task Area SF-43-411-391 under Work Unit 1808-009 at the David W. Taylor Naval Ship Research and Development Center (DTNSRDC). This report was written under Task Area SF-43-422-250, Work Unit 1720-010.

INTRODUCTION TO THE GPRIME/GGEN APPROACH

Finite element modeling demands the generation of large collections of data. Since even a small structure can require large amounts of geometric data, an engineer can spend a great deal of time defining the numerical model of a structure and verifying the correctness of the data. In addition, finite element modeling frequently involves a return to the geometry for more information and details to complete the modeling. Thus complete geometric data and efficient data management are essential if these modifications are to be made easily and quickly.

DTNSRDC's interactive computer program GGEN, which generates finite element models, is different from most other finite element data generators in that it references geometric information that has been defined using the GPRIME geometric language. One advantage of the GGEN-GPRIME approach is that it can refine a generated model without redefining the geometry, because the geometry is readily available from GPRIME. Further, additional geometry may be generated easily through GPRIME. This approach also makes it possible to define a three-dimensional model from a two-dimensional terminal screen or digitizing board. Thus GGEN is fast becoming a valuable tool in the modeling of structures.

The GGEN generator has been implemented as a module of the GPRIME language processor. With this implementation GGEN has access to GPRIME's data base, its data management and viewing options, and its restart capability. GGEN is invoked from GPRIME with the command GGEN whose parameter list may contain names of geometric entities (surfaces, curves, or points) to be immediately activated in GGEN. Under control of GGEN, additional entities may be activated at any time.

Data generation is the principal task performed by GGEN. Elements and grid point coordinates may be generated in large or small quantity, with uniform or non-uniform meshes, by keyboard command or by interactive graphic definition. Large amounts of data may be created or deleted with one keyboard command. The default for bulk mode yields a uniform mesh, but the engineer may set the mesh to provide many broad variations. Individual or group definition of points and elements may be done with keyboard commands, either by typing in the name or by graphic selection. Additionally, creation, deletion, or further refinement of the mesh may be done interactively by selecting functions printed on a screen and then choosing graphically with the cursor the geometry on which to perform the functions. Data handling techniques allow easy management of model sections and display parameters.

GGEN has features both to aid the user during the data generation and to provide finite element data for use in other programs. Plotting defaults display the data as they are generated. However, the user may indicate that individual items are to be drawn or not drawn, and various rendering options allow selection of items for redisplay. The viewing options of GPRIME permit

manual are those established in the GPRIME Program Manual[1*] and should already be familiar to the reader:

1. All key words will be recognized by their first three characters.

2. Items listed in the command formats, printed in upper case. characters, are key words and must be included as shown for that command.

3. Items listed in lower-case characters are symbols for values that the user must provide.

4. Symbolic parameters which begin with the character "a" (e.g., a5) are used to indicate that an alphanumeric parameter is required (e.g., P106); an alphanumeric parameter is one which consists of alphabetic and numeric characters.

5. Symbolic parameters which begin with the character "k" (e.g., k3) are used to indicate that an integer-number parameter is required.

6. Symbolic parameters which begin with the character "r" (e.g., r13) are used to indicate that a real-number parameter is required (in decimal or scientific notation); whole number values need not have a decimal point.

7. Command fields must be separated by commas.

8. Compound parameters, such as WSk1, must not have any separation between the key part ("WS") and the symbolic variable part ("k1").

9. Items included in brackets, "[" and "]", are optional parameters which the user may choose to include.

10. For most (probably all) commands, the key-word parameters will appear first in the parameter string, followed by the symbolic value lists (as in "GENERATE, TRIANGLES, S1, 7, 5, 1").

11. Although GGEN may reference GPRIME variables, GGEN also creates its own variables. These are distinct from GPRIME variables and may be entered into GPRIME only through the GROUP and GPRIME functions described in the section on GPRIME/GGEN communication. The GGEN variables include element Ek, node Pl, group Gm, and workspace WSn, where k,l, and m are the integer values assigned by the user or by the computer and n is the alphanumeric value for the workspace name.

12. The reader is referred to the section on PARTITIONING THE DATA for details on work space definitions and data manipulation within work spaces.

---

*A complete listing of references is given on page 75.

13. The end of a sequence of graphic input must be signaled by some sort of end flag. This flag key will differ with the type of graphic input device being used. For Tektronix 4010-type graphics, the end flag is signaled by entering the "E" key or by selecting the "END" box on the graphic menu.

ENTERING, LEAVING AND SAVING GPRIME/GGEN

Once a user has defined the geometry for a finite element model, a data generation program can be called to create the node points and finite elements required by the analysis program.

<<<:>>>

GGEN

One simple step, the command GGEN, will take the user from the GPRIME Language Processor (in "INTERACTIVE, STORAGE" mode) to the GGEN interactive generator.

Function: To invoke the GGEN program and to establish the GGEN processing environment.

Format: GGEN [,WSk1] [,Pk2] [,Ck3] [,Sk4] [,Gk5] , ... [,a1]

Notes: (a) The optional alphanumeric parameter WSk1 is used to establish a workspace name parameter to be used initially during this GGEN session. If a workspace file named WSi exists on the user's UMF data base, that workspace file will be loaded automatically into the active workspace area of memory for processing. If this parameter is omitted, a default workspace name parameter of "WS000" will be used. When GGEN is entered on subsequent occasions, during the same GPRIME/GGEN session, the name of the last workspace file saved will become the default name parameter. After GGEN has been entered, the GGEN command "RESTORE" can be used to load any other workspace file. If more than one workspace name parameter is specified, the last one listed will be the one that is used.

(b) A workspace file name can be any alphanumeric parameter which begins with the alphabetic characters "WS". The maximum length of the name is set by the version of the GGEN program being used. A length of no more than four characters will be acceptable on any version of the program. To conform

with other GPRIME and GGEN naming conventions, and to make use of the "THRU" ranges of names, workspace file names should begin with the characters "WS" followed by an integer.

(c) The optional alphanumeric parameters Pk2, Ck3, Sk4, Gk5, ..., a1 are the names of GPRIME geometric items which are to be "ACTIVEated" in the workspace area established initially upon entry to GGEN. Items will be "ACTIVATEd" in the order listed. No "THRU" ranges of items will be accepted by this command.

(d) For processing by GGEN, all command names and keyword parameters which are longer than three characters may be abbreviated using the first three characters of the name or parameter. Those abbreviations, although they can greatly reduce the amount of typing, have been avoided in this manual to improve readability.

(e) It is useful to use the GPRIME commands HIDE,ALL and WIPE to clear the screen of GPRIME information before calling GGEN. Figure 1 shows the screen display of the same data in GPRIME and in GGEN.

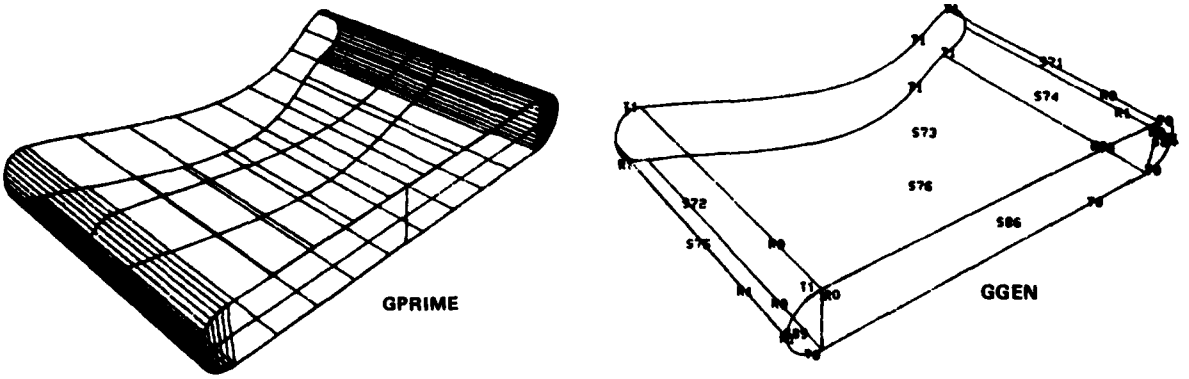


Figure 1 - GPRIME and GGEN Views of the Same Surfaces

END, QUIT

Two commands may be used to make a "normal" exit from GGEN; one will save the current active workspace area before exiting ("END") and the other will not ("QUIT").

Function: To save the current workspace area as a workspace file on the user's data base (UMF) and to exit GGEN.

Format: END

Note: The workspace area will be saved as a workspace file having the name of the current workspace name parameter (See the section on partitioning of the model).

Function: To exit from the GGEN program without saving the workspace area.

Format: QUIT

GGEN will automatically exit whenever a GGEN system error occurs. These errors are beyond the control of the user and indicate a logic error in the program. All other errors are flagged with descriptive messages and should not cause GGEN to exit. On some versions of the program, GGEN watches the clock for a potential "time out" situation (as does GPRIME). On these versions, a warning will be issued, followed by an automatic exit if the warning is not heeded.

SAVING DATA BASES

Our experience with the GPRIME/GGEN and GPRIME/SOLIDGEN[2] programs indicates that the primary manual effort for finite element modeling is now associated with the creation of an adequate geometric model. Clearly, the more time the user has invested in a problem, the more the need for reliable backups of the work. The GPRIME program provides two types of symbolic backup procedures for the user's geometric data base. However, when the user begins generating data with the GGEN program, the only backup procedure that can maintain all the essential data is the creation of multiple copies of the user master file or UMF. The obvious backup procedure, one in which the user copies a partially generated model to a file and then uses the CREATE module to reconstruct the data for review and changes by GGEN, has several defects. These defects include the loss of model and geometry associations and the tedious manual sorting of data into the original partitions. Therefore, for larger problems, we encourage the creation of multiple copies of this data base when the user leaves GPRIME/GGEN. These backup copies can be maintained on tape or disk. Computer centers usually provide some sort of periodic

backup, but we feel that the user is taking an unnecessary risk if he relies on computer center backups alone.

COMMUNICATION BETWEEN THE GGEN AND GPRIME PROGRAMS

The GPRIME language processor and the programs that use the GPRIME geometric descriptions are usually thought of as completely independent programs that communicate only through the user's data base (UMF). The GGEN interactive finite element data generator does not conform strictly to this independence in that it makes use of GPRIME's interactive graphics capability and other interactive features.

<<<:>>>

HELP

GPRIME's on-line user documentation feature, called "HELP", has been expanded to include documentation for the GGEN program. From the GGEN program the HELP command is used to obtain on-line documentation.

Function: To obtain on-line documentation on the use of the GGEN program.

Format: HELP [,a1]

Notes: (a) If the optional alphanumeric parameter a1 is "LIST" or is omitted, GGEN will display a list of all program options for which on-line documentation is available.

(b) If the optional alphanumeric parameter a1 is "INTRODUCTION", a short introductory essay will be displayed. This essay will help orient a new user in applying the program and using other "HELP" commands.

(c) If the optional alphanumeric parameter a1 is the name of one of the program options for which on-line documentation exists, "EDIT" for example, the program will display the basic format required to use the selected option and a short description of its functions.

(d) A copy of the on-line display will be put on the printer output file if GPRIME's PRINT flag is set to "ON".

(e) As when using the GPRIME language processor interactively, the user must have the right side of the graphics screen clear for observing the "HELP" text.

(f) If the user would like to obtain GGEN documentation while under the control of the GPRIME processor, the following command is used:

Format: HELP, COMMAND, GGEN, [,a1]

On-line documentation is obtained under GGEN control using the "PROCESS" command mechanism (described later in this section). The key-word parameters "PROCESS", "COMMAND", and "GGEN" are inserted by GGEN's command processor.

(g) Computer restrictions have limited the on-line documentation to upper-case characters.

<<<:>>>

ACTIVATE

The basic form of communication between the GPRIME user's data base and any of the applications programs is through access to the geometric definitions. For the most part, this access is handled automatically by GGEN whenever the name of a geometric item is mentioned as a parameter in a generation command. However, it is usually prudent to graphically verify that the required geometry is indeed being accessed before large amounts of data are generated. The "ACTIVATE" command permits this preview of the geometry from GGEN's perspective.

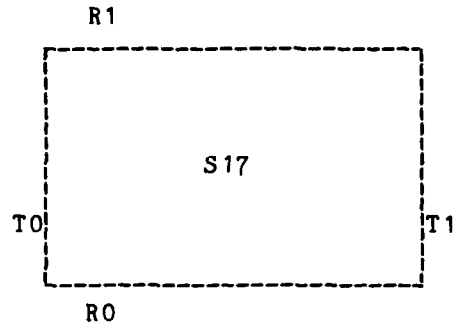
Function: To access geometric items from the user's geometric data base (UMF) and to display their essential characteristics on the graphics screen.

Format: ACTIVATE, a1, a2, ..., az

Notes: (a) The list of alphanumeric parameters a1, a2, ..., az may contain the names of any GPRIME variables that are defined in the user's data base (UMF) and also meaningful to the GGEN program. These items are retrieved from the data base and displayed under the current plot specifications for the active workspace area.

(b) Once "ACTIVATEd", GPRIME geometric names are entered into the workspace tables for reference, permitting these items to be redrawn whenever a workspace file is to be redrawn. Removing these "ACTIVATEd" items from a workspace file (see the "DEACTIVATE" command description later in this section) will have no effect on any part of the model that has already been generated using these items as references.

(c) All GPRIME surfaces are assumed to be bounded by four edges, even if one or more of those edges have zero length. Thus, topologically, all GPRIME surfaces may be viewed as squares. When GPRIME displays a surface, intermediate curves are drawn on the interior of the surface to help convey the shape of the surface. When GGEN displays a surface, only the edges are drawn, since it is assumed that the interior will soon be filled by a finite element mesh. A typical surface, S17, will be displayed as shown in the following diagram:



Any position on the surface S17 can be specified by the parameter pair (Ri,Tj), where both parameters range between zero and one. By default, the finite element mesh will be generated in several bands in which the T-parameter values are held constant for each band and the R-parameter is incremented from zero to one. Similarly, a "T0" will be placed on all curves near the T-0 parameter end for identification.

(d) Geometric points are automatically assumed to be finite element points upon being "ACTIVATEd". If a node ID already exists which is the same as the ID of a point being "ACTIVATEd", the point ID will be incremented by 1000 until a unique node ID is obtained. Because points are converted to nodes, they cannot be "DEACTIVATEd" like other geometric items, but must be "DELETEd" and "PURGEd" to be removed from a workspace file.

(e) GPRIME "GROUP's" may be "ACTIVATEd" and may contain the name of one other GROUP to be "ACTIVATEd". That GROUP name will be the last parameter processed in the current GROUP definition, even if other parameters are present. When GROUPs are "DEACTIVATEd", all items listed except points will be removed from the workspace area. (See also the note on "GROUP, DELETE" in this section.)

(f) The first item "ACTIVATEd" in a workspace area becomes the workspace reference default. If that item is removed, the second item "ACTIVATEd" becomes the workspace default, etc. A new workspace reference default may be established by "ACTIVATEing" any "ACTIVE" item a second time.

<<<:>>>

DEACTIVATE

Often a particular geometric item is no longer needed for reference, for example, when a particular section of the model is complete. The names of such items may be removed from the tables in the active workspace area by the "DEACTIVATE" command.

Function: To remove the names of geometric items from workspace reference tables.

Format: DEACTIVATE, a1, a2, ..., an

Notes: (a) The list of alphanumeric parameters a1, a2, ..., an may contain the names of any GPRIME variables currently "ACTIVATEd". Any names not recognized or not found to be "ACTIVATEd" will be ignored.

(b) All point names will be ignored. Points must be removed from the workspace area by "DELETEing" and "PURGEing".

(c) Items listed in GROUPs specified will be deactivated, but the GROUPs themselves must be removed from the workspace area by the "GROUP, DELETE" command (See below in this section).

(d) "DEACTIVATEion" has no effect on nodes and elements already generated using the "DEACTIVATEd" items as reference.

PROCESS

Clearly, it is not difficult to leave GGEN (with an "END" command), process some GPRIME statements, and restart GGEN again where the user left off (with a "GGEN" command). It does seem useful to have a one-command return to GPRIME, and since we chose to use this sort of mechanism for processing "HELP" and error messages, the "PROCESS" command gives this capability directly to the user.

Function: To temporarily suspend GGEN processing and return to GPRIME for the processing of one statement - either a command or a definition.

Format: PROCESS, a1, a2, ..., an

Notes: (a) The alphanumeric parameters a1, a2, ..., an constitute the GPRIME statement to be processed.

(b) The statement to be processed must consist of one simple statement; macros or in-line definitions will not be processed properly (they will terminate after the first step). Complex statements cannot be handled this way, and a direct return to GPRIME must be made instead.

(c) If the GPRIME command "PROCESSed" causes the graphics screen to be erased, the user must enter subsequent commands to regenerate the GGEN display.

GGEN makes use of GPRIME's graphic display capability to an even greater extent than the GPRIME Language Processor does. Note that GGEN assumes that it has been entered from GPRIME in the "INTERACTIVE, STORAGE" mode and it will not function correctly in any other way. Because all the graphics are under GPRIME's control, the user must initiate a one-statement return to GPRIME, via the "PROCESS" mechanism, to change viewing parameters. This is accomplished with GPRIME's "VIEW" command. This command will cause GPRIME to redisplay any geometric items and graphic tables that the user has currently selected. Thus, it is usually prudent to turn off all of GPRIME's displays before entering GGEN ("HIDE, ALL" is usually appropriate).

GGEN accesses GPRIME's graphic screen transformations to calculate the screen coordinates of nodes and element centroids. These points are recalculated whenever the screen transformations change, whether or not they are actually redrawn. The GPRIME "VIEW" command will not redraw the contents of the current GGEN workspace area or of GGEN's workspace files; thus, the "PROCESS, VIEW, ..." command is usually followed by one or more "DISPLAY" commands.

For reference, GPRIME's "VIEW" command structure, as given in the GPRIME Program Manual[1] is repeated here:

Function: To remove the previous display from the screen and replot it with new viewing parameters.

Format: PROCESS, VIEW, [, EYE, r1, r2, r3] [, TRANSLATE, r4, r5, r6] [, ETOS, r7] [, MODIFY, r8] [, CLIP, k1]

Notes: (a) The view command, with no optional parameters, plots the current display subset using unmodified display parameters.

(b) With the EYE keyword, the real parameters r1, r2 and r3 define the coordinates of the vantage point (location of viewer's eye).

(c) With the TRANSLATE keyword, the real parameters r4, r5 and r6 define the coordinates of the view point (the center of the field of view).

(d) With the keyword ETOS, the real parameter r7 defines the eye-to-screen distance. This parameter may seem awkward and "unnatural" to some users, and its effect, a scaling of the entire plot, can be obtained more "naturally" with the MODIFY parameter.

(e) With the keyword MODIFY, the real parameter r8 defines a scale factor to be applied to the plot defined by the currently defined vantage point, view point, and eye-to-screen distance. Note that the effects of this scaling parameter are not cumulative. Thus, a plot defined by a particular VIEW command will be exactly reproduced by subsequent invocations of that view command.

(f) When the keyword CLIP is included with the VIEW command, the plot will be made with hidden lines removed. The optional integer parameter k1 defines a level resolution for the hidden lines removal processing. The default value for k1 is 32. The hidden-line-removal capability has not yet been implemented in GGEN.

(g) Currently, GPRIME does not give the user control over the orientation of the plot. The basic z-axis will always be oriented vertically, positive upward, on the screen. When looking along the z-axis, the y-axis will be vertical on the screen.

<<<:>>>

GROUP

GPRIME permits users to define GROUPs of items for manipulative convenience. Similarly, GGEN permits both the definition of GROUPs and the use of GPRIME-defined GROUPs. GGEN-defined GROUPs may be confined to one or more workspace files, or they may be known globally throughout the user's geometric

data base (UMF). In order to be known globally, GGEN-defined GROUPs must be processed by the GPRIME command as described at the end of this section.

Function: To define a collection of finite element and geometric items.

Format: GROUP [, a1] [, a2] [, a3, a4, ..., an]

Notes: (a) If the optional alphanumeric parameter a1 is "LIST", or is omitted and no other parameters are given, GGEN will display a list of the names of all GROUPs defined in the current active workspace area.

(b) If the optional alphanumeric parameter a1 is the name of a group and no other parameters are given, GGEN will list the definition of the named GROUP, if such a GROUP is defined in the active workspace area.

(c) If the optional alphanumeric parameter a1 is the name of a GROUP and the list of parameters a3, a4, ..., an is given, GGEN will define a GROUP with the name a1, having the listed items as its definition. If the name a1 is already defined, the optional parameter a2 may be "ADD", in which case the listed items will be added to the current GROUP definition. If "ADD" is not specified, and the GROUP a1 exists, GGEN will not process the command.

(d) The list a3, a4, ..., an may contain "THRU" specifications for nodes and elements known in the active workspace area. All nodes and elements in such "THRU" lists need not be defined. The actual node and element ID's will be stored in the resulting GROUP definition.

(e) The number of items in a GROUP definition should be kept compatible with GPRIME's specifications (for later processing by the GPRIME command, for instance). At present, the limit is 24 items. As in GPRIME, the last item in a GROUP definition may be the name of another group (any GROUP name encountered in the definition will effectively terminate the definition).

(f) If the optional alphanumeric parameter a1 is "DELETE", the optional parameter a2 may be the name of one GROUP definition to be deleted from the active workspace area.

(g) GROUPs have a special function during large bulk data generations under GGEN. It is often necessary to have, in several partitions of the model, points created during a single bulk generation. Points (and elements) defined in GROUPs at the initiation of the bulk generation (using the GENERATE module) will be included in all workspace files created during

the generation. (They will be marked as "duplicate" in all but the first partition created). This feature is most applicable when there is bulk generation on two adjacent surfaces. The first generation is completed and then GROUPs necessary on the boundary between the adjacent surfaces are defined. These inter-workspace file communication devices are admittedly awkward and place a bookkeeping burden on the user, but further development in this area is anticipated.

<<<:>>>

GPRIME

GGEN GROUPs and node points may be made known globally by using the "GPRIME" command. GGEN-defined GROUPs and any points listed as parts of their definitions will be made geometric POINTs and GROUPs in the user's data base (UMF) when processed by this command. The user is responsible for ensuring the uniqueness of the names of the GPRIME POINTs and GROUPs defined via this mechanism; duplicate definitions will be rejected. GROUPs will be stored under the names specified, and POINT names will be generated by "prepending" a "P" to the node ID's specified.

Function: To store GGEN POINT and GROUP definitions in the user's geometric data base (UMF).

Format: GPRIME, Gk1

Notes: (a) The name Gk1 is the name of a GGEN GROUP to be stored.

(b) Node points to be stored must be specified in a GGEN GROUP definition, rather than as command parameters.

SIMPLE BULK DATA GENERATION (GENERATE)

The primary advantage of a finite element data generation program is to enable the user to generate large segments of a model with a few simple commands. Most experienced finite element analysts have developed several special-purpose generators to speed up the modeling of the types of structures they work with regularly. The GPRIME/GGEN program has been designed for a wide range of users and for this reason it may not be as efficient as users' special purpose programs for routine problems.

The "GENERATE" module is GGEN's tool for generating large amounts of data quickly. It is similar to user-written generators in that a few input parameters produce many finite elements and grid points.

"GENERATE" consists of three major submodules. The "PATTERN" submodule is used when a well-ordered set of grid points is available (e.g., from a digitizing board) and the user desires to connect these into elements following a regular pattern. The "QUADRILATERAL" and "TRIANGLE" submodules, which are philosophically more in tune with the GPRIME approach, subdivide a GPRIME surface into a mesh of quadrilateral or triangular elements. Currently, the triangular mesh produced by "GENERATE, TRIANGLES" is identical to the mesh produced by "GENERATE, QUADRILATERALS", if all of the quadrilateral elements are split into triangles along one diagonal. A module to replace the current "TRIANGLE" module is described in the EXPERIMENTAL MODULES section of this report. The primary advantage of the module under development is that it can accommodate changes in the element mesh densities between neighboring surfaces. Figure 2 shows the same surface with triangular and quadrilateral elements.

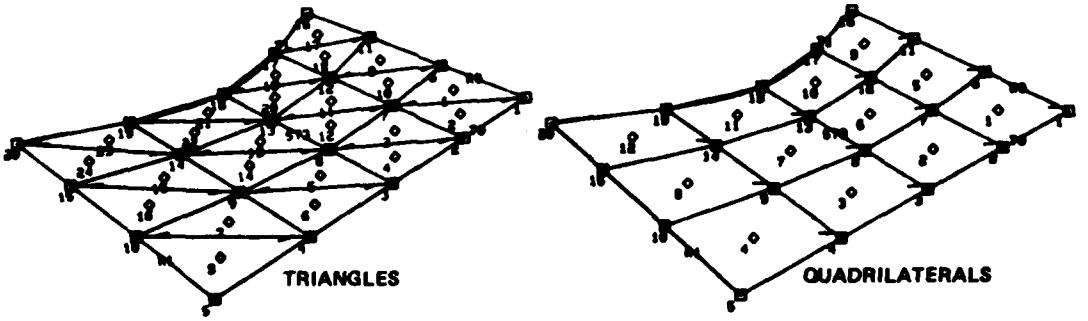


Figure 2 - Bulk Generation of Triangles and Quadrilaterals

Function: To connect a well-ordered set of grid points into a set of finite elements.

Format: GENERATE, PATTERN, [Tk1,] Pk2, Pk3, ..., Pk4, [k5],[k6], [k7], [...], [k8]

Notes: (a) The optional parameter Tk1 is used to specify the type of element to be generated. At present, "k1" is the number of grid points per element. If "k1" is zero or if Tk1 is omitted, only one element will be generated.

(b) The optional parameter k5 indicates the number of times the pattern is to be repeated. If k5 is zero or is omitted, only one element will be generated.

(c) The point ID's Pk2, Pk3, ..., Pk4 define the pattern for the first element to be generated. Subsequent point ID's will be incremented by k5, k6, ..., k7, respectively. A default increment of "1" will be used, if an increment is omitted. Zero increments are permitted.

(d) The character "P" may be omitted from the grid point ID's, if desired.

<<<:>>>

Function: To generate a mesh of quadrilateral or triangular elements over a GPRIME surface.

Format: GENERATE, a1, [a2,] (a3,] [a4,] [k5], [k6], [k7]

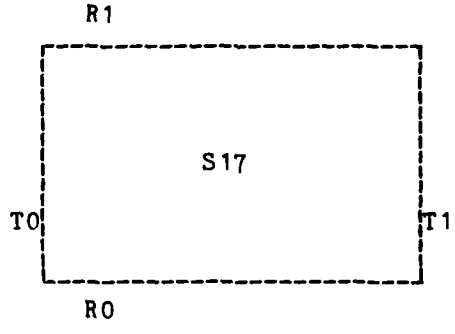
Notes: (a) The alphanumeric parameter a1 may be either "QUADRILATERAL-MESH" or "TRIANGULAR-MESH". There is no default for this parameter that selects the type of mesh to be generated.

(b) The optional alphanumeric parameter a2 is used to specify the GPRIME surface to be subdivided into elements. If this parameter is omitted, the workspace default will be used. If there is no valid workspace default surface (no surface has been "ACTIVATED" or the reference default is a curve), no nodes or elements will be generated.

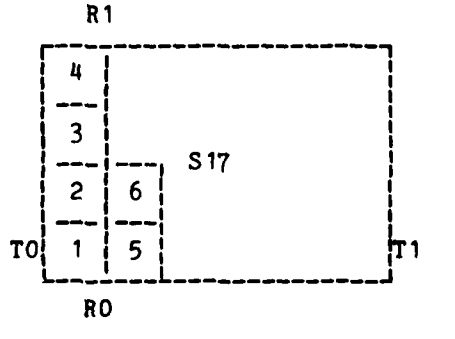
(c) The optional alphanumeric parameter a3 may be used to specify that "NOELEMENTS" are to be generated. This option may be desirable for use with the "GENERATE,PATTERN" command. The default value for a3 is "ELEMENTS".

(d) All GPRIME surfaces are assumed to be bounded by four edges, even if one or more of those edges have zero length. Thus, topologically, all GPRIME surfaces may be viewed as a square. When GPRIME displays surfaces, intermediate curves are drawn on the interior of the surfaces to help convey

the shape of the surface. When GGEN displays a surface, only the edges are drawn, assuming that the interior will soon be filled by a finite element mesh. A typical surface, S17, will be displayed as shown in the following diagram:



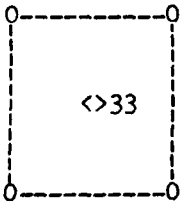
Any position on the surface S17 can be specified by the parameter pair (Ri,Tj), where both parameters range between zero and one. By default, the finite element mesh will be generated in several bands in which the T-parameter values are held constant for each band and the R-parameter is incremented from zero to one. Elements will be generated as in the following diagram:



(e) The optional alphanumeric parameter a4 is used to change the order of element generation. If a4 is "RREVERSE", the R-parameter will be decremented from one to zero. If a4 is "TREVERSE", the T-parameter will be

decremented from one to zero. Similarly, if a4 is "RTREVERSE" both parameters will be decremented from one to zero. Note that each reversal will change the "sense" of the generated elements from clockwise to counter-clockwise and back.

(f) As drawn by GGEN, quadrilateral and triangular elements reflect the "sense" of generation. For element number 33

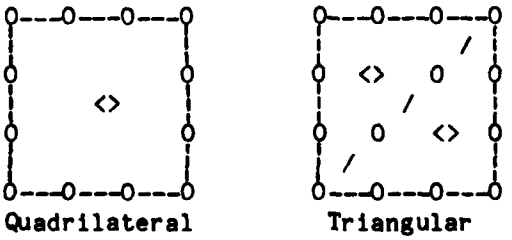


The "tic mark" drawn on the edge of the element is to be considered as half of an arrowhead that points to the first grid point in the element specification, drawn from the last grid point of the element definition. Thus, element 33 is defined in a counter-clockwise sense, starting at the upper left corner of the element. (The tic mark points to the centroid of the projected element.)

(g) The optional key-word parameters a2, a3, and a4 may be specified in any order.

(h) The optional integer parameter k5 is used to specify the number of quadrilateral element blocks that will be generated as the R-parameter is incremented or decremented. Similarly, the integer parameter k6 is used to specify the number of quadrilateral element blocks that will be generated as the T-parameter is incremented or decremented. Default values for both k5 and k6 are 1.

(i) The optional integer parameter k7 is used to specify the number of midside nodes to be used in the definition of the elements. The following diagrams illustrate the elements generated for k5=1, k6=1, k7=2 for quadrilaterals and triangles:



Quadrilateral Triangular

(j) If maintaining the correct "sense" for bulk data generation becomes confusing while operating with GGEN, it is often helpful to return to GPRIME and use the "TRANSPOSE" and "OPPOSITE" definitions to create a new surface with a new "sense".

(k) Often the user will request that the GENERATE module create a finite element model which is larger than can be accommodated in one workspace. (See the section of this manual on the partitioning of finite element models.) As long as one strip of elements can fit into a workspace, GENFRATE will automatically continue the model over several workspaces. Any node points needed in all of these workspaces must be part of an active GROUP in the initial workspace. Any grid points which are repeated in a second, adjoining workspace will be marked as "duplicate".

(l) When a data generation request involves more than one workspace full of data, the initial workspace and all subsequent workspaces, except the last, will automatically be "SAVEd" as files in the user's data base. The last continuation workspace, considered to be only partially full, will not be "SAVEd" automatically.

CONTROLLING THE DETAILS OF BULK GENERATION (SPACING)

The "GENERATE" module should be easy for experienced finite element analysts to use, since it follows elementary schemes for generating finite element data. This section describes a method for modifying the simple generation technique to include some broad variations in the generated mesh. Since the technique is quite powerful, it offers opportunity for elegant solutions to difficult problems, but also has potential for misuse. We suggest that program users skim this section to familiarize themselves with the basic capability and take a few minutes to exercise these features at the graphics terminal before applying them to actual generation problems.

The "SET, SPACING" module is built around B-spline interpolation. It may be helpful for readers to review the B-Spline Functions section of the GPRIME manual[1] to refresh their understanding of the basic concepts used in this section.

The "SET, SPACING" command permits the user to define a weighting function that can be used by the "GENERATE, QUADRILATERALS" (or "TRIANGLES")

command to remap the rectangular finite element mesh and better fit the mesh densities to irregular geometry. Because each GPRIME surface has four real or degenerate edges, "SET, SPACING" can define a mapping for each edge of each surface. The mesh on the interior of each surface will be made to blend smoothly with the specified edge conditions within the bounds set by the edge constraints. Thus smooth meshes will always be produced as long as the weightings for the edges are not in conflict with each other. When such conflicts do arise, the mesh produced will have obvious flaws.

Usually "SET, SPACING" is applied prior to a bulk data generation. In this case conflicts seldom arise when the user's intent is simply to bias the resulting mesh in a particular direction. However, "SET, SPACING" can also be used only to specify the location of grid points on the edges of a surface. If all the grid point locations, not only edge points, are generated, it is possible to impose dozens of constraints, all of which must be satisfied exactly. In this situation it is best to perform the bulk data generation first and then adjust the edge grid points. This caution on the use of "SET, SPACING" is not to discourage users from trying it, but to point out that care must be exercised when constructing a mesh.

Weighting functions can be specified graphically or by specifying parameter values as part of a command. Existing weighting functions can be augmented, and opposite edges of surfaces can be assigned the same weighting function. Graphic specification is most useful for qualitative or aesthetic considerations as well as for verifying current specifications. It is also possible to reverse the order of generation via the weighting functions.

In all, six distinct functions can be performed by the "SET, SPACING" module, and they are described in this section. Most of these functions can be combined, so that the possibilities for mesh refinement become extensive. A simple example of refinement of the mesh of Figure 2 is shown in Figure 3.

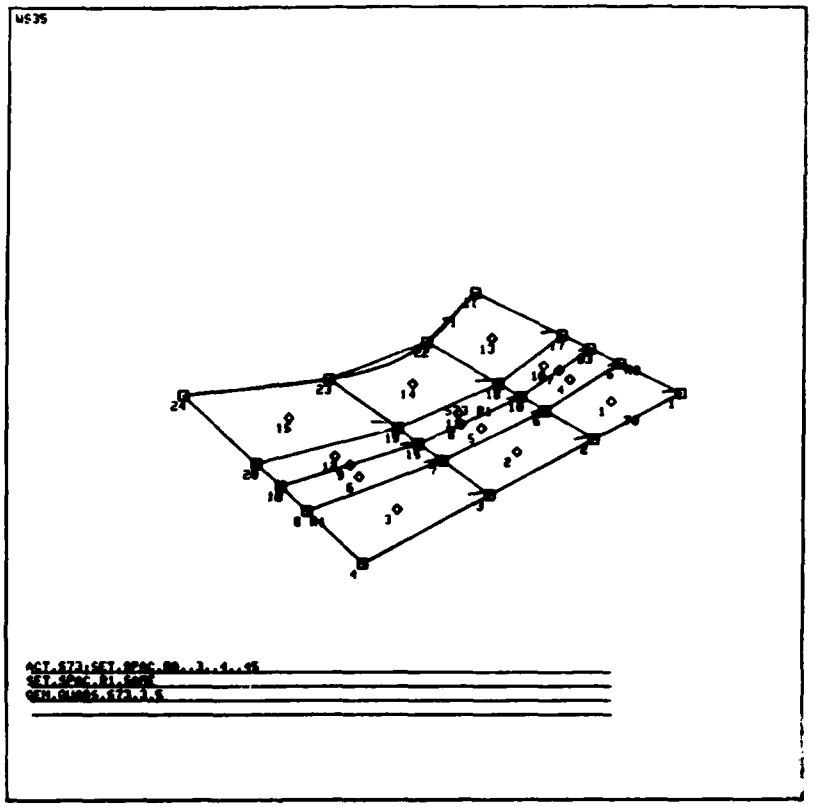


Figure 3 - Simple Mesh Refinement with SET Function

Weighting functions are designed to be used with both GPRIME curves and surface edges, but currently there are no generation modules which will make use of the weighting functions for curves. However, the end points of a curve or surface edge are always implicitly included as part of each weighting function. If the user repeats an end point, the effect will be to bias the mesh heavily toward that end. (Occasionally this feature is useful, but if many elements are defined along that edge, the location of the end grid points will be unpredictable and may even fall outside the reference surface.)

In general, if only one point is picked as a weight, half of the elements will be located on each side of that point. Similar proportionality applies to additional weighting points. For example, if two points are selected, one third of the elements will fall on either side of each weighting point; for three weighting points, one fourth, etc. The number of weighting points must

be the same for opposite edges of all surfaces. Thus, when a weighting is defined for one edge of a surface that has fewer or more weighting points than its opposite edge, the opposite edge will revert to constant spacing.

The "R0, R1, T0, T1" legend displayed by GGEN also indicates the order of parameterization used for curves. The "T0" is displayed near the zero parameter end of the curve. Weighting points may be specified in any order, since the "SET, SPACING" module always sorts the final list of parameters in ascending order (descending order, if the "REVERSE" option is selected).

The features of the "SET, SPACING" module may seem unnecessarily restrictive or incomplete to the user and prompt the question: "If the power of the B-spline fitting and interpolation used by "SET, SPACING" is as robust as advertised, shouldn't "SET, SPACING" be able to accommodate any reasonable situation?" Our answer: "SET, SPACING" is already fairly complex, and adding more features and more complete schemes could unnecessarily confuse the situation, especially because much of the mesh control can be anticipated at the geometry definition level. It is thought preferable to have a compatible geometry model that permits unfettered application of bulk data generation and avoids the module-by-module adjustment of generation parameters. In other words, the cost of developing a more robust "SET, SPACING" capability would be much greater than warranted by the increased utility of the module.

<<<:>>>

Function 1: To specify uniform spacing on a curve or one edge of a surface.

Format 1: SET, SPACING [,a1] [,a2] [,RESET]

Notes: (a) The optional parameter a1 is the name of the GPRIME curve or surface to which this weighting will apply. If omitted, the weighting will apply to the workspace default reference curve or surface.

(b) The optional alphanumeric parameter a2 is used to specify the edge of the surface to which this weighting applies. The options are R0, R1, T0, and T1. The default is T0.

(c) The optional keyword parameter "RESET" will complete the command. If omitted, the command will be considered a graphic input task. Thus, to obtain uniform spacing an "end flag" must immediately follow the command.

Function 2: To specify the location of grid points along a GPRIME curve or along the edge of a GPRIME surface.

Format: SET, SPACING [,a1] [,a2] [,r3, r4, ..., rn]

Notes: (a) The optional parameter a1 is the name of the GPRIME curve or surface to which this weighting will apply. If omitted, the weighting will apply to the workspace default reference curve or surface.

(b) The optional alphanumeric parameter a2 is used to specify the edge of the surface to which this weighting applies. The options are R0, R1, T0, and T1. The default is T0.

(c) If the optional list of real parameters "r3, r4, ..., rn" is omitted, grid point locations will be defined via graphic interaction. If the points picked are on the interior of the surface rather than precisely on the edge (or slightly outside) of the reference surface, the points will be moved to the edge along parametric lines.

(d) Since graphic definition can be imprecise, grid point definition should be carried out with the display at the highest magnification possible.

(e) If the optional list of real parameters "r3, r4, ..., rn" is specified, the interior grid points will be located at the points defined by the given parametric values along the specified edge. End points are automatically included and should not be specified unless multiple grid points are required.

(f) When all points have been defined graphically, an end flag (e.g., the "E" key) must be entered. There will always be a beginning and ending grid point along every edge, so the "SET, SPACING" command is used to define interior points only.

(g) Grid points are not generated by "SET, SPACING". Modules like "GENERATE, QUADRILATERALS" must be employed for that function. It is the user's responsibility to ensure compatibility between the "SET, SPACING" definitions and the data generation modules. That is, if a number of grid point locations have been set along an edge, say n interior nodes, the corresponding data generation command must specify that n+1 elements are to be generated along that edge.

Function 3: To specify a general bias in the mesh along a GPRIME curve or along one edge of a GPRIME surface.

Format: SET, SPACING [,a1] [,a2] [,r3, r4, ..., rn]

Note: This command is identical to that of Function (2). The difference is governed by the generation module command. If the two specifications do not agree, i.e., if more or fewer points are defined than generated, the resulting mesh will be proportional to the spacing defined.

<<<:>>>

Function 4: To specify that the mesh bias along one edge of a GPRIME surface is to be the same as along the opposite edge of that surface.

Format: SET, SPACING [,a1] [,a2], SAME

Notes: (a) The optional parameter a1 is the name of the GPRIME curve or surface to which this weighting will apply. If omitted, the weighting will apply to the workspace default reference curve or surface.

(b) The optional alphanumeric parameter a2 is used to specify the edge of the surface to which this weighting applies. The options are R0, R1, T0, and T1. The default is T0.

(c) If, after specifying "SAME" for one edge, the user changes the edge opposite of a surface, the "SAME" specification must also be respecified.

<<<:>>>

Function 5: To modify, by adding weighting points, a previously defined weighting function along a GPRIME curve or edge of a GPRIME surface.

Format: SET, SPACING [,a1] [,a2], ADD [,r3, r4, ..., rn]

Notes: (a) The optional parameter a1 is the name of the GPRIME curve or surface to which this weighting will apply. If omitted, the weighting will apply to the workspace default reference curve or surface.

(b) The optional alphanumeric parameter a2 is used to specify the edge of the surface to which this weighting applies. The options are R0, R1, T0, and T1. The default is T0.

(c) If the optional list of real parameters "r3, r4, ..., rn" is omitted, the additional points must be defined via interactive graphics. GGEN will display existing points before requesting the new input. When additions are complete, an "end flag" must be entered. The user may graphically verify the current weighting points by requesting graphic additions without defining any new points.

(d) If the optional list of real parameters "r3, r4, ..., rn" is given, those parameters will be added to the current list.

<<<:>>>

Function 6: To maintain the current weighting function along a GPRIME curve or along the edge of a GPRIME surface, but to specify that the order of generation is to be reversed.

Format: SET, SPACING [,a1] [,a2], REVERSE

Notes: (a) The optional parameter a1 is the name of the GPRIME curve or surface to which this weighting will apply. If omitted, the weighting will apply to the workspace default reference curve or surface.

(b) The optional alphanumeric parameter a2 is used to specify the edge of the surface to which this weighting applies. The options are R0, R1, T0, and T1. The default is T0.

(c) If an existing "REVERSEd" weighting is modified, "REVERSE" must be respecified.

INTERACTIVE DATA GENERATION AND MODIFICATION

The utility of simple bulk finite element data generators is greatly diminished by the fact that most structures, both natural and man made, have some irregularity that can't be modeled by a simple algorithm. This difficulty can be overcome by (1) designing more sophisticated algorithms, (2) writing more model-specific data generation programs, or (3) manual intervention. When dealing with dozens of pages of computer printout, the third option seems to be clearly impractical. No analyst wants the tedious job of modeling structural irregularities, since they are usually the most complicated regions on the structure. The first two options also have their drawbacks as well; either the algorithms get too complicated for easy application,

or they lack sufficient generality, so that a new generator is required for each new type of problem.

Convenient interactive graphics makes the manual intervention option much more attractive. If the model can be changed by manipulating grid points and elements on a graphics screen, instead of by changing hundreds of numbers in the model data, the manual modeling of irregular regions doesn't seem quite so impractical and may be the most cost effective way of handling general modeling problems. This is the approach taken by GGEN.

Two modules, CREATE and EDIT, make up the heart of GGEN's interactive capabilities. Functionally, these two modules are nearly identical, but they differ in their modes of application. The CREATE module is driven by specific user commands for selecting each of the functions. The EDIT module presents a list of options from which the program user selects the desired function using interactive graphic input. The list of options is referred to as a "graphic menu" and the interactive graphic input is accomplished using a device such as a crosshair cursor, a light pen, or a digitizing tablet. The CREATE module does permit interactive data generation and modification as does EDIT, but it also permits passive definition of grid points and elements through explicit specification of grid point coordinates and element connectivity.

Graphic input techniques are similar for all types of graphic devices. In this section we will assume that the graphic input device is similar to a Tektronix storage-tube screen with a crosshair cursor that is positioned by thumb wheels.

GGEN MODULE CREATE

The GGEN module CREATE is actually a family of submodules which can perform 17 distinct functions. These functions parallel the functions available in the EDIT family of modules which may be selected from a graphic menu. Thus, all the EDIT functions can be invoked as commands when the graphic menu is not being displayed.

<<<:>>>

Function 1: To define nodes by direct entry of node ID and coordinate data.

Format: CREATE, NODES [,a1], Pk2, r3, r4, r5

Notes: (a) The optional alphanumeric parameter a1 is the name of a GPRIME curve or surface which will be added to the node definition for information only.

(b) The parameter Pk2 is the node ID to be assigned to the point being defined.

(c) The three real parameters r3, r4, and r5 are the coordinates of the point being defined.

(d) If a node already exists with an ID of Pk2, that node will be redefined.

<<<:>>>

Function 2: To define next node by direct entry of coordinate data.

Format: CREATE, NODES [,a1], r2, r3, r4

Notes: (a) The optional alphanumeric parameter a1 is the name of a GPRIME curve or surface which will be added to the node definition for information only.

(b) The three real parameters r2, r3, and r4 specify the coordinates of the point being defined.

(c) A unique node ID will be assigned to this node.

<<<:>>>

Function 3: To redefine (move) a node by direct entry of the ID and coordinate data.

Format: CREATE, NODES [,a1], Pk2, r3, r4, r5

Notes: (a) This function is similar to the sequence "DELETE, Pk2" followed by "CREATE, NODES, Pk2"

(b) If the node does not exist, a new node will be defined.

<<<:>>>

Function 4: To define a specific node using graphic input.

Format: CREATE, NODES [,a1], Pk2

Notes: (a) The optional alphanumeric parameter a1 will be the name of the GPRIME curve or surface used for graphic reference, if specfied. Otherwise, the workspace default will be used.

(b) If only an "end flag" is entered, no node will be defined.

<<<:>>>

Function 5: To define the next node using graphic input.

Format: CREATE, NODES [,a1]

Notes: (a) The optional alphanumeric parameter a1 will be the name of the GPRIME curve or surface used for graphic reference, if specified. Otherwise, the workspace default will be used.

(b) A unique node ID will be assigned to each node defined.

(c) This function defaults to repetitive definition of many nodes. To terminate a sequence of nodes, an "end flag" must be entered. If only an "end flag" is entered, no nodes will be defined.

<<<:>>>

Function 6: To redefine (move) a specific node graphically.

Format: CREATE, NODES [,a1], Pk2

Notes: (a) The optional alphanumeric parameter a1 will be the name of the GPRIME curve or surface used for graphic reference, if specified. Otherwise the workspace default will be used.

(b) This function is equivalent to the sequence "DELETE, Pk2" followed by "CREATE, NODES, Pk2"

(c) If no node is already defined with an ID of Pk2, a new node will be created.

<<<:>>>

Function 7: To define a sequence of nodes graphically.

Format: CREATE, NODES [,a1]

Notes: (a) Repetitive definition is the default for CREATE

(b) The sequence of nodes will be terminated whenever an end flag is encountered. If only the "end flag" is entered, no nodes will be defined.

<<<:>>>

Function 8: To delete a specified node.

Format: CREATE, NODES, Pk1

Notes: (a) The parameter Pk1 is the ID of the existing node to be deleted. An "end flag" is required to terminate any graphic input.

(b) Graphic input may be used to define a new node with the same node ID.

<<<:>>>

Function 9: To define elements by direct entry of element ID and connectivity data.

Format: CREATE, ELEMENTS [,Tk1], Ek2, Pk3, Pk4, ..., Pkn

Notes: (a) The optional alphanumeric parameter Tk1 will be included in the definition of this element for information purposes only.

(b) The parameter Ek2 is the element ID to be assigned to the element being defined.

(c) The sequence of alphanumeric parameters Pk3, Pk4, ..., Pkn are the grid point ID's of the points that connect to the element being defined.

(d) If an element already exists with an ID of Ek2, that element will be redefined.

(e) Integer numbers k3. k4, ..., kn can be used to specify the grid point ID's as well as Pk3, etc.

<<<:>>>

Function 10: To define the next element by direct entry of connectivity data.

Format: CREATE, ELEMENTS [,Tk1], Pk2, Pk3, ..., Pkn

Notes: (a) The optional alphanumeric parameter Tk1 will be included in the definition of this element for information purposes only.

(b) This list of alphanumeric parameters Pk2, Pk3, ..., Pkn contains the grid point ID'S of the points that connect to the element being defined.

(c) A unique element ID will be assigned to this element.

(d) The integer numbers k2, k3, ..., kn can be used to specify the grid point ID's as well as Pk2, etc.

<<<:>>>

Function 11: To redefine (move) an element by direct entry of the ID and connectivity data.

Format: CREATE, ELEMENTS [,Tk1], Ek2, Pk3, Pk4, ..., Pkn

Notes: (a) This function is similar to the sequence of "DELETE, Ek2" followed by "CREATE, ELEMENTS, Ek2"

(b) If the element does not already exist, a new element will be defined.

(c) The integer numbers k3, k4, ..., kn can be used to specify the grid point ID's as well as Pk3, etc.

<<<:>>>

Function 12: To define a specific element using graphic input.

Format: CREATE, ELEMENTS [,Tk1], Ek2

Note: The optional alphanumeric parameter "Tk1" is used to specify that there will be k1-nodes per element in a sequence of elements. If Tk1 is omitted, an "end flag" must be used to indicate the completion of an element definition. If only an "end flag" is entered, no element will be defined.

<<<:>>>

Function 13: To define the next element using graphic input.

Format: CREATE, ELEMENTS, [Tk1]

Notes: (a) The optional alphanumeric parameter "Tk1" is used to specify that there will be k1-nodes per element in a sequence of elements. If Tk1 is omitted, an "end flag" must be used to indicate the completion of an element definition.

(b) A unique element ID will be assigned to each element defined.

(c) This function defaults to repetitive definition of many elements. To terminate a sequence of elements, an "end flag" must be entered. If only an "end flag" is entered, no elements will be defined.

<<<:>>>

Function 14: To redefine (move) a specific element graphically.

Format: CREATE, ELEMENTS [,Tk1], Ek2

Notes: (a) The optional alphanumeric parameter "Tk1" is used to specify that there will be k1-nodes per element in a sequence of elements. If Tk1 is omitted, an "end flag" must be used to indicate the completion of an element definition.

(b) This function is equivalent to the sequence "DELETE, Ek2" followed by "CREATE, ELEMENTS, Ek2"

(c) If no element is already defined with an ID of Ek2, a new element will be created.

<<<:>>>

Function 15: To define a sequence of elements graphically.

Format: CREATE, ELEMENTS [,Tk1]

Notes: (a) Repetitive definition is the default for the CREATE module.

(b) The optional alphanumeric parameter "Tk1" is used to specify that there will be k1-nodes per element in a sequence of elements.

(c) The sequence of elements will be terminated whenever an end flag is encountered. If only the "end flag" is entered, no elements will be defined.

Function 16: To delete a specified element.

Format: CREATE, ELEMENTS, Ek1

Notes: (a) The integer parameter k1 is the ID of the existing element to be deleted. An "end flag" is required to terminate any graphic input.

(b) Graphic input may be used to define a new element with the same element ID.

<<<:>>>

Function 17: To create a sequence of elements and associated node points.

Format: CREATE, NODES, ELEMENTS [,a1] [,Tk2]

Notes: (a) The optional alphanumeric parameter a1 is the name of a GPRIME curve or surface that will be used for graphical reference in creating node points. If it is omitted, the workspace default will be used.

(b) The optional integer parameter k2 is used to specify that there will be k2 nodes per element in a sequence of elements. If Tk2 is omitted, the completion of an element definition must be indicated by an "end flag".

(c) Unique node and element ID's will be assigned to all nodes and elements defined in this way.

GGEN MODULE EDIT

The GGEN module EDIT is actually a family of submodules that can perform 19 distinct functions. Most of these functions have direct counterparts in the CREATE module which can be selected by typing in a command.

Figure 4 is a facsimile of the GGEN/EDIT menu and shows the options available to the user. Options B, C, and D pertain specifically to digitizing board input. They are mentioned in this section and will be described in more detail in the Digitizing Board section.

A.	REDRAW WORKSPACE
B.	SWITCH TABLET/CROSS
C.	ALIGN MENU (UL,LR)
D.	ALIGN ORTH (PT1,PT2,PT3)
E.	E N D (INPUT/EDIT)
G.	DELETE NODES
H.	(CHANGE)
I.	(LAST)
J.	DELETE ELEMENTS
K.	(CHANGE)
L.	(LAST)
M.	CREATE NODES
N.	CREATE ELEMENTS
O.	ELEMENTS + NODES
P.	2 NODES/ELEM.
Q.	3 NODES/ELEM.
R.	4 NODES/ELEM.
Z.	REPEAT MESSAGE
*	TASK COMPLETED
**	IMPROPER OPTION
***	MISSED BOX
****	POINT NOT ON C/S
*****	OTHER
0	ZVAL
*1	S1
2	S2
3	C3

Figure 4 - GGEN/EDIT Menu

The user's ability to precisely define points using an interactive device will vary with the device and the scale at which the model is being displayed (along with many other factors). For graphically locating existing points and elements GGEN will accept any entry which falls within a square enclosing the box drawn at a grid point or which falls within a square enclosing the diamond drawn at the centroid of an element. Any points entered outside these squares will result in a "missed box" error message.

For grid point definition, points will be defined wherever the graphics line of sight, through the crosshair cursor, intersects with the reference curve or surface. If no intersection is found on the curve or surface, but the line of sight passes near an end of the reference curve or near the edge of a reference surface, a point will be defined using the closest point on the curve or the closest point on the edge of the surface. (Thus, the user can define a point that lies precisely on the edge of a surface by picking a point just outside that surface.)

<<<:>>>

Function: To interactively create and modify a finite element model

Format: EDIT [,a1] [,a2] [,MENU] [,ORTHOGRAPHIC] [,ZVALUE, r3]

Notes: (a) The optional alphanumeric parameter a1 is used to specify the name of the GPRIME reference curve or surface to be used in the interactive definition of grid points. If omitted, the workspace default will be used. If the required curve or surface is "active" in the workspace, this reference curve or surface can be specified during the execution of the EDIT module.

(b) The optional alphanumeric parameter a2 is used to specify whether a terminal with "CROSSHAIRS" or a graphic "TABLET" is to be used. The default is "CROSSHAIRS" and no other options will be recognized. This option can also be selected during the execution of the EDIT module.

(c) The optional key-word parameter "MENU" is used to indicate that a graphic "MENU" must be realigned on the graphic tablet before graphic input can be accepted. The default is that no realignment will be necessary. This option can also be selected during the execution of the EDIT module and the alignment can be performed at any time using the "ALIGN" command.

(d) The optional key-word parameter "ORTHOGRAPHIC" is used to indicate that an "ORTHOGRAPHIC" drawing must be realigned on the graphic tablet before graphic input can be accepted. The default is that no realignment will be necessary. If an orthographic drawing is being used and "MENU" was specified, realignment of the orthographic drawing will be necessary for correct interactive data definition. This option can also be selected during

the execution of the EDIT module. The alignment can be performed at any time using the "ALIGN" command.

(e) If the optional key-word parameter "ZVALUE" is specified, the optional real parameter r3 can be used to specify the third- or Z-coordinate value to be used with the points defined from orthographic drawings on the graphic tablet. If a "ZVALUE" parameter is not specified, and the user selects an option which would use that value during the execution of the EDIT module, the definition of all points will contain a z-coordinate value in the plane of the graphic tablet or display screen (whichever is being used).

(f) The EDIT functional options are displayed in the graphic menu area at the right of the screen. To select an option from the EDIT menu, the user may either press the keyboard key that has the alphanumeric character displayed at the left of the desired menu box, or he may move the crosshair cursor over the desired menu box and then press the "space bar" on the keyboard. GGEN will acknowledge the user's option selection by redrawing the box around the chosen option. In either case no "return" key entry is required or permitted. (If the "return" is accidentally pressed, subsequent interaction with the graphics screen will lose synchronization. If this happens, the user should enter "end flags" until an exit from EDIT is reached and then begin the execution of the EDIT module again.) Although GPRIME and GGEN usually permit the user to anticipate the completion of various tasks and to type ahead of the program prompts, this cannot be done in interactive graphics. The user must wait for the appearance of the crosshair cursor (when it is expected) before striking any keys. Typing ahead has the same effect as using the "return" key whenever graphic interaction is involved.

(g) Most graphic functions are terminated with an "end flag"; however, choosing another option from the menu will have the same effect. Thus, the use of the "end flag" is required only when the user wishes to leave the EDIT module.

(h) To avoid menu clutter, abbreviated titles are used wherever possible. Item "G" is the "Delete Nodes" option, item "H" is the "Delete and Recreate Node" or "Change" option, and item "I" is the "Delete Last Node Created" option. A message area follows the alphabetic option section of the menu. Coded messages are included for the termination conditions encountered most frequently with this module. When one of these conditions occurs, GGEN

will ring the bell on the user's terminal once for each asterisk shown on the corresponding message box on the menu. GGEN will also highlight (redraw) the box around the message being issued. If the termination condition is not one of the four listed, GGEN will ring the bell five times and highlight the "OTHER" box on the menu. To obtain further information, the user must leave EDIT and enter a "MESSAGE" command to see the complete text of the last message from the program.

(i) The last portion of the menu area is the optional "Reference Curve and Surface Table". This numbered section of the menu is used with the "Create Nodes" and the "Create Elements & Nodes" options to temporarily change the reference curve or surface for defining nodes. The default reference curve or surface is the one entered as a parameter with the current EDIT command. If none was entered, the workspace default is the reference curve or surface.

(j) Specific functions available through menu options are described in the next section.

<<<:>>>

EDIT MODULE FUNCTIONS

Function A: To redraw the portion of the model defined in the currently-active workspace.

Note: The entire screen will be cleared and then the currently-active model segment will be redrawn.

<<<:>>>

Function B: To switch from "CROSSHAIRS" mode to "TABLET" mode or from "TABLET" mode to "CROSSHAIRS" mode.

Notes: (a) Each time this option is selected, the interactive graphic mode will be switched.

(b) In the "TABLET" mode, changes in the model will not be displayed until the user chooses to terminate the current function. Then all recent changes will be displayed before processing continues.

Function C: To align the menu on the graphic tablet.

Notes: (a) The graphic menu used on a graphic tablet must be either a hard copy of the screen menu, or a proportional facsimile of that menu.

(b) The user must enter two points from the graphic tablet to locate the upper left and lower right corners of the menu.

<<<:>>>

Function D: To align an orthographic drawing on the graphic tablet.

Note: The user will be requested to enter the coordinates of three points on the drawing.

<<<:>>>

Function E: To terminate with an "end flag".

Notes (a): (1) This flag is used to terminate logical loops when they occur in processing interactive function requests.

(b) If there are no pending logical loops, this flag will terminate EDIT processing.

<<<:>>>

Function G: To graphically delete grid points from the model and to restore deleted grid points to a "not deleted" status.

Notes: (a) This option is equivalent to the "Delete Nodes" command entered with none of the optional parameters.

(b) The user selects grid points to be deleted by placing the crosshair cursor over the box drawn at the desired grid point and then pressing the "space bar". GGEN will indicate the change in status by placing an "X" in the box at the selected grid point.

(c) If the user selects a deleted grid point, GGEN will indicate the change in status to "not deleted" by redrawing the box and displaying the node ID at the location of the selected point.

Function H: To interactively change the definition of a grid point.

Notes: (a) The user selects the nodes to be changed by placing the crosshair cursor over the box at the current location of the grid point and pressing the "space bar". EDIT will mark that node as deleted and will "remember" its node ID. That node ID will be assigned to the next grid point defined. Note that EDIT will then "PURGE" this deleted node definition from the workspace; thus, it cannot be restored.

(b) After the deletion of the selected node, EDIT automatically switches to option "M", "Create Nodes". If the user chooses not to define a node via this function, other options or commands may be used to redefine the node.

<<<:>>>

Function I: To delete the last grid point defined.

Note: Each time this option is selected, the most recently created node in "not deleted" status will be marked "deleted".

<<<:>>>

Function J: To graphically delete elements from the model and to restore deleted elements to a "not deleted" status.

Notes: (a) This option is equivalent to the "Delete Elements" command entered with none of the optional parameters.

(b) The user selects elements to be deleted by placing the crosshair cursor over the diamond drawn at the center of the element and then pressing the "space bar". GGEN will indicate the change in status by crossing out the diamond drawn at the selected element.

(c) If the user selects a deleted element, GGEN will indicate the change to "not deleted" status by redrawing the element.

Function K: To interactively change the definition of an element.

Notes: (a) The user selects the element to be changed by placing the crosshair cursor over the diamond drawn at the center of the element to be changed and then pressing the "space bar". EDIT will mark that element as "deleted" and will "remember" its element ID. That element ID will be assigned to the next element defined. Note that EDIT will then "PURGE" this deleted element from the workspace; thus, it cannot be restored.

(b) After the deletion of the selected element, EDIT automatically switches to option "N", "Create Elements". If the user chooses not to define an element via that function, other options or commands may be used to redefine that element.

<<<:>>>

Function L: To delete the last element defined.

Note: Each time this option is selected, the most recently created element in "not deleted" status will be marked "deleted".

<<<:>>>

Function M: To graphically define grid points for the finite element model.

Notes: (a) The user defines grid points by moving the crosshair cursor to the desired location on the reference curve or surface and pressing the "space bar". In this mode a new node will be created each time the "space bar" is pressed. To terminate this mode, the user must enter an "end flag".

(b) If the user wishes to use some reference curve or surface other than the current default, he may select from the "Reference Table" (displayed at the bottom of the menu area) options 0, 1, ..., n , which correspond to the curves and surfaces that are active in this workspace. The default reference curve or surface is either entered as a parameter with the current EDIT command, or, if none was specified, comes from the workspace default. In the latter case it is the first curve or surface "ACTIVATEd", or the last curve or surface that has been "ACTIVATEd" twice (or more).

(c) If the reference is to "ZVAL", the third coordinate of the points created will be the r3 parameter value specified as a parameter with the current EDIT command. If none was specified, the points defined will lie in the plane of the graphics tablet or screen.

(d) This option is equivalent to the "Create Nodes" command entered with none of the optional parameters.

<<<:>>>

Function N: To graphically define elements for the finite element model.

Notes: (a) The user defines elements by graphically selecting the grid points to which the element is to be connected. One element definition is assumed to be complete whenever an "end flag" is entered. If an element definition is followed by a second "end Flag", this function will be terminated.

(b) If option "P", "Q", or "R" is selected while in this mode, every pair, triple, or quadruple of points, respectively, will be assumed to define one element.

(c) All points chosen for defining elements must be defined and have a status of "not deleted".

(d) This option is the equivalent of the "Create Elements" command entered with no other optional parameters. If a secondary option of "P", "Q", or "R" has been selected, the option is the same as a "Create Elements" command entered with a "T2", "T3", or "T4" parameter, respectively.

<<<:>>>

Function O: To graphically define elements for the finite element model and optionally to define grid points as needed.

Notes: (a) This option is identical to option "N" except that, when a grid point selection would have resulted in a "missed box" error, option "M" will be invoked to attempt to define a grid point at the specified location.

(b) Suboptions for both options "M" and "N" may be selected.

(c) This option is equivalent to the command "Create Elements & Nodes".

<<<:>>>

Function Z: To highlight the last termination message issued.

Notes: (a) GGEN will highlight the message block corresponding to the last message issued (no bells, however; "highlighting" means redrawing the box).

(b) If the message issued was not one of the four shown in the "message area" of the menu, the user must leave the EDIT module and execute a "MESSAGE" command to see the full text of the message given.

PARTITIONING THE MODEL FOR INTERACTIVE PROCESSING (WORKSPACES)

Almost every finite element model involves the storage of a large amount of numeric data, either in computer memory or on an auxiliary storage device such as a disk unit. However, few computers have enough memory to accommodate practical finite element problems, and the disk searches required to identify names of nodes and elements selected graphically on the display screen are inefficient and time-consuming. The incompatible requirements of storage space and processing speed present a problem.

In GPRIME all the geometric definitions and most other data required for GPRIME's operation are stored on disk in a data base referred to as the User's Master File (UMF). This type of storage would not be efficient for use by the GGEN generator. To obtain the rapid response required by interactive graphics processing, we have restricted the amount of editable data available to the GGEN program at any given time by the use of "workspaces" and have achieved very acceptable results.

A workspace is an area of the computer's central memory in active use on the problem. One or more workspaces may be saved on the UMF data base and recalled at a later time. With the entire GPRIME geometric data base always accessible from the UMF, users have great flexibility in selecting data (surfaces, curves, points, and groups) from which to build finite element models. For computers whose interactive computing environments have central

memory restrictions, the maximum size of an active workspace is preset by the program. The minicomputer version of GGEN, which assumes that a large virtual memory operating system is available, permits the user to make tradeoffs between fast access and convenient partitioning of the model data, and thus to set the size of the active workspace area in virtual memory.

Management of workspaces may be thought of in terms of the management of files within a data base. The user's GPRIME data base (the UMF) contains many types of data, which may be arranged for use by GGEN in files corresponding to partitions of the finite element model. It is assumed that the finite element model is too large for GGEN to process as a unit. The model must therefore be partitioned into files, or "workspaces", each of which will be small enough to be processed by GGEN.

These workspace files are managed within the UMF data base by three operations, all carried out from within the GGEN program: (1) Storing a newly created workspace file (using the SAVE command), (2) Replacing an existing workspace file with a new version (using the SAVE command), and (3) Removing an unwanted workspace file (using the WSPURGE command).

Workspace files are given names with the RENAME and SAVE commands. To load one partition (workspace file) of the model into computer memory for review or modification by GGEN, the RESTORE command is used. RESTORE reads the named workspace file into GGEN's active memory.

To protect the user's data, GGEN will automatically store copies of active workspaces (the workspace file currently being processed) at crucial points in the processing. At these crucial points, the workspace files will be stored in the UMF under the name given on the last SAVE, RESTORE, or RENAME command. (Thus, if the user wants to keep several versions of the same workspace file, he should specify a unique name for the version he is currently modifying. Otherwise, GGEN will automatically store the modified version in place of the original version in the UMF data base.) GGEN will write a copy of the currently active workspace to a workspace file in the UMF data base in the following situations:

- Whenever the "SAVE" command is encountered
- Whenever the commands "END", "HELP", and "PROCESS" are encountered

- Whenever a "DISPLAY" command is encountered which requests that specific, non-active workspace files be displayed
- Whenever a workspace is filled during bulk data generation
- Whenever a GGEN system error occurs.

All the information about the user's finite element model is contained in the workspace files stored in the UMF data base (i.e., there are no global parameter files). Within each workspace file is a parameter table which contains information used in generating the model, and each workspace file must contain some information about the remainder of the model, particularly about neighboring partitions and the node and element ID's generated so far in the creation of the model. At the present time, the user must ensure that all this information is available in the workspace files.

One way to ensure consistency from one partition to the next is to generate the model in the order of adjacent partitions. When moving from one partition to its neighbor, the user first "SAVEs" the completed partition, names the new partition, deletes all the elements that have been generated previously, and deletes all the grid points generated previously, except those that are common with the new partition (which are marked as "duplicate"). The system is then ready for the generation of a new partition. This method ensures that the global parameters, such as the ID's that have been used, are always up to date in the last partition generated. This is the method used by the "GENERATE" module when the segment being generated is too large to be generated as one partition.

This method cannot be used when points are needed for several adjacent partitions. Those common points can be stored as GPRIME geometric points from one partition and "ACTIVATEd" in the other partitions. The GGEN modules "GROUP", "GPRIME", and "ACTIVATE" are needed to accomplish this data transfer. Additionaly it is sometimes convenient or necessary to have the generation of element ID's and grid point ID's begin with a number other than the one that would follow the last one generated in a neighboring partition. The "SET, PARAMETER" module can be used to modify the usual course of events.

Manual partitioning of the workspaces is usually accomplished by one of the following command sequences:

1)	SAVE	Store completed workspace
	RENAME	Assign unique new name to new partition
	DELETE, ELEMENTS	Delete all elements
	DELETE, NODES	Delete most grid points
	PURGE	Free deleted space
	SET, DUPLICATE, ALL	Mark remaining points as duplicates
2)	SAVE	Store completed workspace
	RENAME	Assign unique new name to new partition
	RETAIN, BEGIN	Mark all elements and points "deleted"
	RETAIN, [points and GROUPs]	Change some points to "not deleted"
	RETAIN, END	Mark those points as duplicates and free deleted space

Each time GGEN is entered, an active workspace area is created in memory. A workspace name parameter is established either from the parameter on the GPRIME "GGEN" command, or, if that has been omitted, from the GGEN default name parameter, which will be the name of the last workspace file saved during this session or "WS000" on first entry to GGEN. If a workspace file exists on the user's UMF data base with the same name as the current workspace name parameter, that workspace file will be loaded into the active workspace area of memory; otherwise, an empty workspace area will be established. If, upon entry, the GPRIME command GGEN contained in its parameter list various items to be "ACTIVATEd", those items will be "ACTIVATEd" by GGEN's ACTIVATE module prior to further processing. At the time of the first entry into GGEN for any given problem, the UMF data base will contain no workspace files. These files are added to the UMF only by the GGEN "SAVE" module.

WORKSPACE DISPLAY FUNCTIONS

Function: To list the names of all workspace files stored in the user's UMF data base.

Format: PLOT, EVERYTHING, NODRAW
DISPLAY, WS0, THRU, WS99[9]

Notes: (a) The currently active workspace is "SAVEd" and the names of all workspaces are displayed in the upper left corner of the screen. The list will begin with the most recently "SAVEd" file and continue in reverse chronological order. This list will also be copied to the printer file if GPRIME's PRINT flag is set to "ON". Finally, the workspace file that was active prior to this display sequence will then be "RESTOREd" to active status.

(b) For convenience, these commands should be made from an "empty" active workspace so that the "PLOT, EVERYTHING, NODRAW" command does not change meaningful "PLOT" options in a workspace that contains model data.

(c) Instead of itemizing workspace names, the word "THRU" may be used for a range of workspaces. The maximum length of the workspace name in the "THRU" range will be determined by the version of GGEN being used, (999 for CDC and 99 for VAX).

<<<:>>>

Function: To display the contents of any and/or all non-active workspace files.

Format: DISPLAY, WSk1, WSk2, THRU, WSk3, WSk4, ...

Notes: (a) This particular form of the DISPLAY command does not erase the screen at any time.

(b) The contents of each workspace file will be drawn according to the PLOT specifications in effect in the currently active workspace area. No "diamonds" will be drawn on any non-active elements and the grid point "box" will be reduced to a solid bullet for all non-active grid points.

(c) If any of the specified workspace files do not exist, a null file will be processed for those names listed explicitly. The numeric range of workspace WSk2, THRU, WSk3 will be displayed in reverse chronological order of their creation and storage on the UMF data base. Non-existent files in the specified numeric range will be ignored.

(d) For convenience, these commands should be made from an "empty" active workspace area, so that the PLOT parameters do not have to be changed for any workspace file that contains model data.

(e) The user may wish to enter an "ERASE" command, prior to this command, to remove earlier work from the screen. Alternatively, the user may wish to display the active workspace first, using a DISPLAY command with no parameters, which will also erase the screen.

WORKSPACE MAINTENANCE FUNCTIONS

Function: To establish an empty workspace area with the name specified as the workspace name parameter of the currently active workspace.

Format: CLEAR [,GO]

Notes: (a) This command should be used only to revert to a "virgin" status when the user is totally dissatisfied with the progress of the current generation session and wishes to start over. This command affects only the current active workspace area in memory and does not affect any workspace files stored in the user's UMF data base.

(b) This command clears the active workspace area in memory so that it is as if GGEN were being entered for the first time. However, the workspace name parameter will not be changed, and numbering of the data will begin at 1.

(c) This command, if given during a sequence of modifications to a workspace file, will not be executed if there are outstanding changes which have not been "SAVEd". If the optional key-word parameter "GO" is specified, or if the command is entered a second time after a "not SAVEd" warning has been issued, the command will be executed, whether or not there are "unSAVEd" changes.

(d) GGEN considers all changes to a workspace area as potentially significant modifications, even changes in simple parameter settings. Thus, the user will get a "not SAVEd" warning even when only minor changes have been made.

(e) This command is similar to a "RESTORE" command for a non-existent workspace file, except it will not change the current workspace name parameter.

Function: To copy the currently active workspace area to the printer file

Format: DUMP [,k1]

Notes: (a) If the optional integer parameter k1 is zero or omitted, the "DUMPed" copy will be formatted according to workspace tables. If k1 is less than zero, the "DUMP" will be made unformatted. If k1 is greater than zero, both forms will be copied.

(b) This command is intended primarily for system maintenance of GGEN/GPRIME.

<<<:>>>

Function: To set the workspace name parameter for the currently active workspace.

Format: RENAME [,k1]

Notes: (a) If the optional alphanumeric parameter WSi is specified, that parameter will be used for the workspace name parameter associated with the currently active workspace. This name will be displayed in the message area in the upper left corner of the screen. The name will also be listed in the printer file if GPRIME's print flag is set to "ON".

(b) If the optional name parameter WSi has been omitted, GGEN will assign a unique name for the workspace name parameter. This name will be the next name in numeric sequence from the last name used in the UMF data base. Displays and listings of that name will be the same as if the name parameter had been specified by the user.

(c) Numbering of data resumes with the next consecutive number after the last ID used for points and elements.

<<<:>>>

Function: To load a workspace file from the UMF data base into the active workspace area of memory for processing by GGEN.

Format: RESTORE [,WSk1] [,GO]

Notes: (a) If the alphanumeric workspace file name parameter WSk1 has been specified, GGEN will attempt to load the named workspace file from the

user's UMF data base. If no such file exists, an empty workspace (identical to one set up initially by GGEN and by the "CLEAR" command) will be established with the specified name.

(b) If the optional workspace file name parameter WSk1 is omitted, "RESTORE" will attempt to load a workspace file with the same name as the workspace name parameter associated with the currently active workspace. If no such file exists, an "empty" workspace area will be established in memory. This empty workspace area is identical to one created initially by GGEN and by the "CLEAR" command.

(c) This command, if given during a sequence of modifications to a workspace file, will not be executed if there are outstanding changes which have not been "SAVEd" on the curent workspace. If the optional key-word parameter "GO" is specified, or if the command is entered a second time after a "not SAVEd" warning has been issued, the command will be executed, whether or not there are "unSAVEd" changes.

(d) GGEN considers all changes to the active workspace area as potentially significant modifications, even changes in simple parameter settings. Thus, the user will get a "not SAVEd" warning even when only a minor change has been made.

(e) If an empty workspace area is created, the numbering parameters, that is the IDs created for nodes and elements, will be reset to 1.

<<<:>>>

Function: To copy the contents of the current active workspace area to a workspace file on the UMF data base.

Format: SAVE [,WSk1]

Notes: (a) If the optional alphanumeric parameter WSk1 is specified, that name will be used as the name of the workspace file that will be copied to the UMF data base. If omitted, the workspace file name will be taken from the workspace name parameter associated with the currently active workspace.

(b) If the workspace name parameter associated with the currently active workspace area is different from the workspace file name specified WSk1, the workspace name parameter will be changed to WSi. This change will

be reflected in the new workspace name display in the screen message area and the new entry on the printer file.

(c) If the workspace file name used is the same as an existing workspace file, that older file will be replaced by the current copy. No warnings will be issued when workspace files are replaced by the SAVE module.

(d) There are no differences between a user-specified SAVE and the various automatic SAVEs triggered by GGEN.

(e) An automatic save is almost always made when a GPRIME/GGEN system error occurs, except if the error resulted from an attempt to save a workspace file.

<<<:>>>

Function: To mark elements and nodes as duplicates of elements and nodes defined in other workspace files.

Format: SET, DUPLICATE [,ALL]

SET, DUPLICATE [,Pk1] [,Pk2, THRU, Pk3] [,Ek4]
[,Ek5, THRU, Ek6] [,Gk7]

Notes: (a) Since workspace files cannot directly access data or communicate with other workspace files, each workspace file must contain enough information to completely display the partition of the model contained in that file. This makes it necessary for the grid points on the boundaries of partitions to be duplicated at least once. When a bulk generation module automatically extends a model across partitions (thus, across workspaces) it will mark the second set of grid points as "duplicate", so that only one copy of the grid points will be transferred to the analysis program when the model is completed. The "SET, DUPLICATE" module also gives the user the ability to mark grid points as "duplicate" when manually partitioning the model.

(b) The optional key-word parameter "ALL" and the optional list of alphanumeric parameters Pk1, Pk2, THRU, Pk3, Ek4, Ek5, THRU, Ek6, Gk7, ... permit the user to select items to be marked "duplicate". The default option is "ALL".

(c) Duplicate grid points will be displayed as "not active", even in "active" workspaces.

(d) The GROUP name parameters listed, such as Gk7, will not cause these GROUPs to be marked as "duplicate", but will cause all grid points and elements referenced in those GROUPS to be marked as "duplicate".

(e) Duplicate elements are not necessary for creating a non-redundant model partition, but this capability has been included for completeness.

<<<:>>>

Function: To modify parameters associated with GGEN's active workspace area in memory.

Format: SET, PARAMETERS, a1, k2

Notes: (a) If the alphanumeric parameter a1 is LEID, the workspace parameter indicating the last element ID assigned by GGEN will be set to the integer value k2. This parameter will cause the next element ID created by GGEN to be k2+1.

(b) If the alphanumeric parameter a1 is LPID, the workspace parameter indicating the last node point ID assigned by GGEN will be set to the the integer value k2. This parameter will cause the next node ID created by GGEN to be k2+1.

(c) If the alphanumeric parameter a1 is IPTOL, the workspace parameter that controls the sensitivity (or exactness) of GGEN's interactive graphic selection will be set to the integer value k2. The default value (100) of this parameter will indicate that a point or element will be selected if the user chooses a point within the square or diamond that is displayed with the point or element. The value of k2 specified by the user permits selection of some percentage of that sensitivity—usually for distinguishing between closely spaced items.

(d) If the alphanumeric parameter a1 is IWARN, the workspace parameter indicating the point at which the user would like to be reminded that the current active workspace area is nearly filled, will be set to the integer parameter k2. This parameter indicates the percentage of fill of the node and element tables that will be accepted before any warnings are issued.

Note that bulk data generators also use this parameter to determine when to partition a large model over several workspace files. Default value is 85.

<<<:>>>

Function: To display the size and usage status of the currently active workspace area in memory.

Format: STATUS [,WS]

Notes: (a) This command will display the size and the percent usage of all tables in the active workspace area, as illustrated in Figure 5.

(b) The key-word parameter "WS" is optional for this command because "WS" is the default setting.

```
      WS1   WS3
ACTIVE NODES...     20
DELETED NODES...    0
ACTIVE ELEMENTS...  18
DELETED ELEMENTS... 0
PERCENTAGE NODE AND ELEMENT SPACE ALREADY USED...   1
ACTIVE GROUPS...    0
   TABLE LENGTH     50
   PERCENTAGE USED  0
ACTIVE CURVES AND SURFACES...   1
   TABLE LENGTH     50
   PERCENTAGE USED  0
SUBSTRUCTURES...
   NUMBER OF BLOCKS 0
   TABLE LENGTH     0
   PERCENTAGE USED  0
STRUCTURES...
   NUMBER OF BLOCKS 0
   TABLE LENGTH     0
   PERCENTAGE USED  0
C/S WEIGHT...
   NUMBER OF BLOCKS 1
   TABLE LENGTH     100
   PERCENTAGE USED  0
ELEMENT CONTINUATION...
   NUMBER OF BLOCKS 0
   TABLE LENGTH     100
   PERCENTAGE USED  0
ELEMENT TYPE...
   NUMBER OF BLOCKS 4
   TABLE LENGTH     100
   PERCENTAGE USED  66
TABLET HOLDING TABLE...
   NUMBER OF BLOCKS 0
   TABLE LENGTH     100
   PERCENTAGE USED  0


RESTORE,WS3
STATUS
```

Figure 5 - Example of STATUS Table

Function: To remove a workspace file from the UMF data base.

Format: WSPURGE, WSk1, WSk2, WSk3, THRU, WSk4, ..., WSkn

Notes: (a) This command permanently removes a workspace file from the user's UMF data base. The data storage space freed by this command will be made available for additional entries in the data base.

(b) Any request for a range of workspace names, e.g., WSk3, THRU, WSk4, must be made with names beginning with "WS" followed by an integer parameter. For individual requests, any legal alphanumeric name beginning with "WS" may be specified.

(c) Any request to "WSPURGE, WSk1" will have no effect on a currently active workspace area with the name parameter "WSk1".

DELETING AND CHANGING NODES AND ELEMENTS

GGEN has two modes of node and element deletion. The first mode, called "DELETE", permits restoration of the deleted item if the deleted item was selected by mistake. A second delete will restore the deleted item. Items "DELETEd" in this manner will not be drawn when the active contents of the workspace are redisplayed, but adjacent elements will "remember" the location of the deleted nodes and will be drawn as if the deleted node were still active. An example of "DELETEd" data before and after redraw is given in Figure 6.

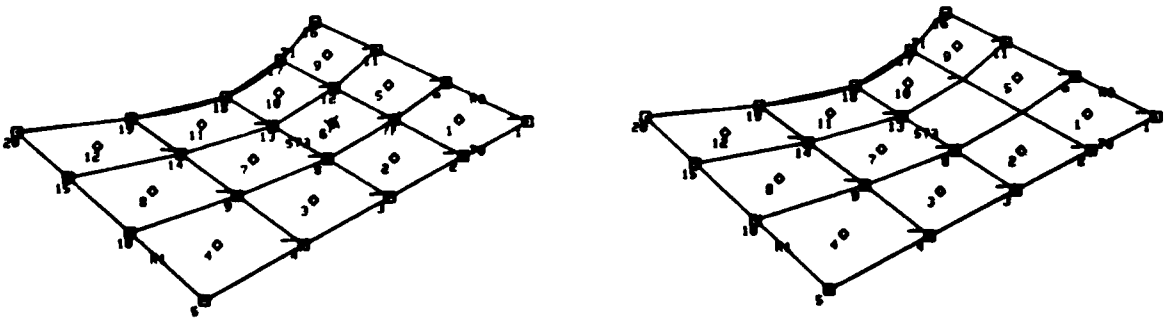


Figure 6 - DELETEd Data Marked with "X"; Removed on Redraw

The second mode of deletion, called "PURGE", removes all references to the deleted item and makes the storage occupied by the deleted items available for new entries in the workspace. "PURGEd" items will not be shown when the workspace is redrawn, and all undefined gridpoints in the model will be drawn to the origin of the model (default location of all undefined items).

Under GGEN, nodes and elements may be changed by first "DELETing" them and then "CREATEing" them in the new location. However, it is usually easier to let "CREATE" handle both the deletion and creation functions, since CREATE can operate graphically without reference to element and node ID's.

When an item is "DELETEd", a status word is negated (from "not deleted" to "deleted" or from "deleted" to "not deleted") for that item. When an item is "PURGEd", all references to the purged item are removed.

When workspaces are changed, it is often useful to purge most of the existing model but to retain those nodes on the boundary of the section modeled earlier. This can be accomplished using the "RETAIN" command. (Deletions of GROUPs are processed under the "GROUP, DELETE" command and purges of workspaces are processed under the "WSPURGE" command.

DELETE,PURGE

Function: To flip (negate) the "not deleted"/"deleted" status of elements and nodes.

Format: DELETE, Ek1, Pk2, Ek3, THRU, Ek4, ...

Notes: (a) The current status of all items listed will be negated if they exist. Items listed by the user but not defined in this workspace will be ignored.

(b) Wholesale deletions may produce unexpected results, if unforeseen dual deletions are specified. For example, an item previously deleted will be restored by a second delete.

<<<:>>>

Function: To permanently remove node and element definitions from a workspace.

Format: PURGE, a1

Notes: (a) If the alphanumeric parameter a1 is "NODES", all nodes currently marked as "deleted" will be irrevocably removed from this workspace.

(b) If the alphanumeric parameter a1 is "ELEMENTS", all elements currently marked as "deleted" will be irrevocably removed from this workspace.

(c) If the alphanumeric parameter a1 is "BOTH" (default, if not specified), all nodes and elements marked as "deleted" will be irrevocably removed from this workspace.

<<<:>>>

Function: To permanently remove all nodes which are not connected to any elements.

Format: PURGE, NOCONNECTIONS

Note: Any node which is not connecte to any element will be purged from this workspace.

<<<:>>>

Function: To permanently remove all elements which reference undefined (or deleted) nodes from this workspace.

Format: PURGE, INCOMPLETE

Notes: (a) Any incomplete element will be irrevocably purged from this workspace.

(b) This command can be used to remove blocks of elements from a model by deleting a set of strategically placed nodes.

RETAIN

Function: To mark all nodes and elements in this workspace as "deleted".

Format: RETAIN, BEGIN

Notes: (a) This command first executes a "PURGE, BOTH" instruction to remove all nodes and elements marked "deleted"; all remaining items will then be marked "deleted".

(b) To mark all items "not deleted", the following command may be used:

RETAIN, E0, THRU, E999, P0, THRU, P999

(c) If the user is unsure about the status of deleted items, say nodes, the display command should be involked:

DISPLAY, P0, THRU, P999

before using the PURGE or RETAIN command.

(d) Instead of deleting a list of items, sometimes it is easier to use the RETAIN command, as part of a three-step RETAIN sequence:

```
RETAIN, BEGIN                Step 1
RETAIN, items
DELETE, items          }     Step 2
EDIT [delete items]
RETAIN, END                  Step 3
```

This sequence is convenient for retaining a few nodes and elements when changing workspaces. Step 1 marks all items deleted. Step 3 is identical to the "PURGE, BOTH" command. Thus these two steps will remove <u>all</u> nodes and elements from this workspace. Step 2 permits the status of some items to be flipped to "not deleted"; these items will remain following the "RETAIN" sequence.

<<<:>>>

Function: To mark some nodes and elements as "not deleted".

Format: RETAIN, Ek1, Pk2, Pk3, THRU, Pk4, ...

Notes: (a) This command is similar to the "DELETE" command, except that the status of items selected will be set to "not deleted" rather than flipped (negated).

(b) Although this command is usually part of the three-step "RETAIN" sequence, it may be invoked at any time.

Function: To make all current deletions permanent and to release unused storage within the current workspace.

Format: RETAIN, END

Notes: (a) This command is an alias for the "PURGE, BOTH" command. IT has been provided for cosmetic compatibility with the closely related RETAIN commands.

(b) All changes produced by this command are permanent and irrevocable.

(c) All remaining nodes and elements will be marked "DUPLICATE".

CONTROLLING THE DISPLAY OF THE MODEL

GGEN's control over the graphics display is limited to the specification of the imformation to be plotted and the manner in which it is to be displayed. GPRIME's "VIEW" command must be invoked to change the way in which the program user will view the model. Two commands are available for GGEN's plot control: PLOT and DISPLAY.

<<<:>>>

Function: To specify items to be plotted and/or labeled in the current active workspace area.

Format: PLOT [,a1] [,a21, a31, a41, ...] [,a22, a32, a42, ...] ...

Notes: (a) The PLOT command is processed in a left-to- right order. Thus, a later specification may override all or a portion of an earlier specification.

(b) If the optional parameter a1 is given as "RESET", all plotting parameters will be set to their default values before subsequent specifications are applied. The default value for this parameter is "NORESET", and further specifications are applied to the current value of the parameters.

The groups of optional parameters a2i, a3i, a4i, ... are used to specify plotting values. a2i may be any of the following key words:

CURVESANDSURFACES

ELEMENTS

EVERYTHING

MENU

POINTS

REFERENCETABLE

SURFACESANDCURVES

The default value for a2i is "EVERYTHING". Note that CURVES and SURFACES cannot be specified seperately.

The parameters a3i, a4i, ... are used to specify values for the items specified using a2i. The following key words apply:

DRAW

NODRAW

LABELS

NOLABELS

SHRINK

NOSHRINK

The key words "SHRINK" and "NOSHRINK" apply only to the drawing of the finite elements. "SHRINK" will cause each element to be drawn shrunken away from its connecting grid points, toward the element centroid. This pattern can help users to find voids in their models and to identify two-noded elements that may lie along an edge of a plate or solid element.

The default values are "DRAW", "LABELS", and "NOSHRINK".

(c) PLOT parameters are saved with each workspace file and will be in effect when that workspace is "RESTOREd".

<<<:>>>

Function: To display the contents of the current workspace area or to display individual items.

Format: DISPLAY [,a1] [,a2] ...

Notes: (a) If no optional parameters are specified, the screen will be cleared and the current workspace area will be redisplayed using the current "PLOT" specifications.

(b) The optional parameters ai may include curve names, surface names, point names, element names, and the key words "MENU" and "REFERENCETABLE".

(c) Specific DISPLAY requests override global plot parameters. "DELETEd" (but not "PURGEd") POINTS and ELEMENTS will also be shown when specifically requested.

SPECIAL PURPOSE TRANSFORMATIONS (ADJUST)

Function: To modify a finite element model by moving grid point data normal to the GPRIME reference surface on which the data has been defined. ADJUST permits the use of inner- or outer-surface reference data, while conforming to the usual convention that plate and shell grid points are located at the midsurface of the elements.

Format: ADJUST, Sk11, Sk12, r1, Sk21, Sk22, r2, ...

Notes: (a) The Skn1 are the reference surfaces to which the thickness surface Skn2 will be used to adjust the position of the grid points by a distance "rn" normal to the surface Skn1.

(b) The base position of the grid points will be recalculated by the ADJUST module each time it is invoked. Thus, repeated use of ADJUST will result in identical grid point positions each time. There are no cumulative effects on the position of the grid points calculated by adjust.

(c) Thickness surfaces should be set up to correspond to the geometric reference surfaces with which they will be used. Thickness values are specified as the x-coordinate of the thickness surface; y- and z-coordinates of the thickness surface are ignored. When the reference surface is defined by digitized data, say, a 10-by-10 grid, the thickness data should also be given on a 10-by-10 grid. If the thickness is constant, then a 2-by-2 surface will suffice. It could be defined in many ways; the simplest is probably a direct definition of the thickness surface desired:

```
S10, SURFACE, 0, 2, 2, 0, 0, 3
.0001, 0, 0
.0001, 0, 0
.0001, 0, 0
.0001, 0, 0
```

(d) There are few rules to govern the creation of thickness surfaces, so whatever is given to ADJUST will be used. Thus, the user must understand the process and must ensure that the specifications given are

valid. Linearly varying thickness can also be defined with a 2-by-2 surface; other types of regular variation are limited only by the user's imagination.

COMMUNICATION WITH OTHER PROGRAMS (PUNCH)

The "PUNCH" module is GGEN's device for converting the user's finite element model from internal format to one that can be recognized by other programs. It is quite primitive in its current form and the data produced by this module will usually require some manual editing before the form will be acceptable to an analysis program. We expect that future versions of the program will permit the user to define a wide variety of formats.

<<<:>>>

Function: To convert the finite element model partition contained in the active workspace area to quasi-NASTRAN format.

Format: PUNCH [,a1] [,a2]

Notes: (a) The optional parameter a1 is used to specify the type of data to be converted: "POINTS", "ELEMENTS", or "BOTH". The default is "BOTH".

(b) The optional parameter a2 is used to specify whether the entire partition is to be converted ("ALL") or only those items that have been changed ("CHANGE") since the last time this workspace file was "PUNCHed". The default is "ALL".

(c) Converted finite element data will be written to the file FEDATA in the order in which the data have been defined.

(d) Items which have been "DELETEd" but not "PURGEd" will be converted to dummy elements and GRID points to indicate that previous occurrences of these items must be edited from previous FEDATA entries.

(e) Element and node data will be converted to NASTRAN's 80-column-format records, each with ten fields, eight columns wide. At present, all elements are given the same dummy element name. The element property ID field will contain the numeric portion of the GPRIME curve or surface name referenced in generating that element.

(f) Each workspace file must be "RESTOREd" and "PUNCHed" to convert the complete model. If the user wishes GGEN to keep track of whether changes

have or have not been written to the FEDATA file, each workspace file must be "SAVEd" after "PUNCHing". This may not be the most desirable course if the user intends to "PUNCH" copies of the model at several different times.

USING A DIGITIZING BOARD WITH GGEN

The digitizing board or table commands in GGEN allow the EDIT functions to be controlled by a "mouse", or hand cursor control. This capability provides a larger picture or drawing area than is available with the graphics terminal screen. The command SWITCH, which is necessary to invoke this drawing mode, has not yet been implemented as a keyboard command. However, once this command is implemented, the EDIT command ALIGN may be used as in the EDIT mode of GGEN. With this command the user positions a hard copy of the menu on the digitizing board. It is assumed that area to the left of this position represents the screen. The scaling and orientation of the drawing section are then determined by three input points. These positions are given according to keyboard prompts following the user's command ALIGN. As many as 50 nodes or elements may be entered before they are drawn. An END command will cause drawing at any time.

<<<:>>>

Function: To position the menu on the digitizing board.

Format: ALIGN,MENU

<<<:>>>

Function: To provide scaling and orientation to the drawing on the digitizing board.

Format: ALIGN,ORTHOGRAPHIC

EXPERIMENTAL GGEN MODULES

Several GGEN modules have been written which were not intended for general use. They usually were meant to solve a one-time problem, demonstrate a principle, or were an intermediate product in the development of a general

capability not yet completed. These modules are briefly described in this section, so that the techniques used will not be completely lost and so that they may serve as prototypes for future development.

Each of these modules must be invoked by the experimental driver module, ZZZ, rather than by a module name.

GGEN has many subordinate modules in a production status which are not directly accessible to the user. The names of production modules must be entered in the master module name table in subroutine "GGXXEQ" before the modules can be invoked by name. The experimental driver ZZZ permits any existing module to be executed regardless of its status. One parameter may be passed to the module, in addition to any command parameters the module may require. Usually, non-user-callable modules do not have command parameters. The experimental driver call has the following format:

Format: ZZZ, [ZPAR, k1,] a1, a2, ..., an

Notes: (a) The optional integer parameter k1 will be passed to the module invoked.

(b) The alphanumeric parameter a1 is the name of the module to be executed.

(c) The alphanumeric parameters, a2, ..., an are the command parameters which may be accessed by the module a1.

Currently three modules have this experimental status: DHIR, TRM, and TRIANGLE.

GGEN MODULE DHIR (EXPERIMENTAL)

Function: To calculate skewed strains (e1, e2, and e12) from a given geometric surface (S1) and a displacement surface (S2); calculations will be made for the parameter values specified and the values will be written to the FEDATA file.

Format: ZZZ, DHIR, Sk1, Sk2, [E, r3, NU, r4, ALPHA, r5,] k6, k7, r8, [rs1, rs2, ..., rsk6, rt1, rt2, ..., rtk7]

Notes: (a) Keyword parameters have the following defaults: r3 (Young's modulus) 3.0 x 10**7; r4 (Poisson's ratio) 0.3; r5 (parameter increment used in computing derivatives via differencing) 0.1.

(b) k6 is the requested number of output points in the s-direction on the surface. k7 is the requested number of output points in the t-direction on the surface.

(c) If r8 is zero or omitted, uniformly spaced values will be used. Otherwise, the listed "rski" values and the "rtkj" values will be used.

(d) DHIR is not an "official" GGEN user command and thus must be invoked by the ZZZ experimental driver.

(e) This module was developed in an attempt to derive useful strain data from holographic displacement data. Preliminary results were not encouraging, and the project was terminated.

<<<:>>>

GGEN MODULE TRM (EXPERIMENTAL)

Function: To transform 6-noded triangular elements with arbitrarily located midside nodes into 6-noded triangular elements with midside nodes centered on each leg of the triangle. The module transforms all 6-noded elements contained in the current workspace. Format: ZZZ, TRM

Notes: (a) This transformation is for cosmetic purposes only, at least for NASTRAN's CTRM6 elements for which it was developed.

(b) TRM is not an "official" GGEN user command and thus must be invoked via the ZZZ experimental driver.

GGEN MODULE TRIANGLE (UNFINISHED, EXPERIMENTAl)

Function: To automatically generate a triangular mesh as a transition region between sections of a model with different element densities.

Format: ZZZ, TRIANGLE, k1, k2, k3, k4, k5

Notes: (a) k1, k2, k3, k4 specify the number of elements on the top, bottom, right, and left of the region, respectively.

(b) The integer parameter k5 specifies the number of midside nodes for the triangular elements being generated.

(c) At present this module generates a mesh on a fictitious surface S1 which is a unit square. This mesh can be mapped onto an actual GPRIME surface S1 using the ADJUST command.

GGEN DIFFERENCES ON OTHER COMPUTERS

The GPRIME interactive modeling system[1] was first developed to run on CDC 6000 computers. However, as congestion on CDC computers has increased, so has response time for interactive users. CDC users have found themselves with restricted memory and time available in the interactive mode. When the tremendous growth in computer technology made it financially feasible for many Navy design and analysis engineers to have dedicated minicomputers, it was requested that GPRIME be made available on other computer systems. A version of the GPRIME/GGEN program runs on the DEC VAC 11/780 minicomputer.

The virtual memory and the favorable interactive environment of the DEC VAX 11/780 32-bit minicomputer made it a strong contender for selection. It was felt that, if GPRIME could be made to run on the VAX with the 32-bit word, it could be rather easily put on any 32-bit computer.

Although initially GPRIME was to be a relatively machine-independent system, memory restrictions and the 60-bit word of the CDC computers used in its development made this goal impractical. The overlay features, bit-packing in data arrays, and character recognition of the CDC version made it incompatible with the VAX. Although most changes to GPRIME for the VAX version are transparent to the user, several have caused changes in the user-computer interface, in data and file handling, and in some program capablities. These differences include operating system procedures, file management, variable name length, defaults, data management, and the loss of some CDC features. Furthermore, the GPRIME staff was able to recognize trade-offs between the CDC and VAX computer families due to differences in their basic architecture; such information is included to guide the experienced user. For convenience to the user, operating procedures and GPRIME differences are also included here.

COMPUTER TERMINAL CONTROLS

Although experienced VAX users are familiar with the setup features of the terminals they use for communication with a VAX, the first-time user can avoid frustration by observing the following information or prompts, screen

control and control characters. First of all the prompt given under VMS for the user to type a command is the $. Second, the VAX does not display commands typed-ahead of the prompt. Users who make a practice of doing this on CDC or other computers may find it less frustrating and less confusing not to type ahead on the VAX.

The user should type the following commands after the $ prompt:

SET TERM/NOECHO prevents seeing every character twice

SET TERM/UPPERCASE set characters to uppercase

For convenience to the user, the control characters shown in Figure 7 are reprinted here from the VAX-11 Text Editing Reference Manual[4*].

INITIALIZATION PROCEDURES

The command procedure for executing GPRIME on the VAX resembles very closely the CDC procedure. It is invoked interactively with the command:

@GPRIME [P1] [P2] [P3] [P4] [P5] [P6]

All parameters have default values except P1, which is the user-defined User Master File (UMF), the data base containing data generated by GPRIME.

If the user types @GPRIME HELP, the following on-line documentation will appear:

```
$ @GPRIME HELP
!
!     COMMAND PROCEDURE TO RUN GPRIME
!
!     @GPRIME P1 P2 P3 P4 P5 P6
!         P1 = NAME OF OUTPUT UMF FILE
!         P2 = USER DIRECTORY (MUST INCLUDE BRACKETS)
!         P3 = OLD UMF (RESTART) OR "NEW" (INITIAL)
!         P4 = INFILE OR " " (DEFAULT INPUT IS TERMINAL)
!         P5 = SPDATA FILE OR "" (DEFAULT = SPDATA.DAT)
!         P6 = FEDATA FILE OR "" (DEFAULT = FEDATA.DAT)
!     ANY OMITTED PARAMETERS BETWEEN PARAMETERS MUST BE
!     SPECIFIED WITH ""
!
!     @GPRIME P1   WILL ASSUME CURRENT USER DIRECTORY
!                  AND NEW UMF FILE
!     @GPRIME   WILL PROMPT FOR NEW UMF FILE NAME
!
$SET NOVERIFY
```

DEL	(DELete, or RUBout, or CANcel) This character deletes the previous input character. Successive DEL characters remove previous characters one by one. Any number of characters can be deleted, up to the last carriage return or escape typed. The way this deletion is represented on your terminal depends on the type of terminal. On CRT terminals, the characters are physically deleted and the cursor is moved backward. On hard-copy terminals, the deleted characters are echoed in reverse order, and set off within backslashes (\).
CTRL/U	This character, typed before an input line is complete, deletes the entire line being input. You can then retype the line. CTRL/U is generated by typing u or U while holding down the CTRL key. It is echoed as ^U.
CTRL/S	This character, typed while output is in progress, suspends the output until you type CTRL/Q. CTRL/S is not echoed.
CTRL/Q	This character resumes output suspended by CTRL/S. CTRL/Q is not echoed.
CTRL/O	This character interrupts output in progress. SOS continues to send output to the terminal, but the terminal discards it. SOS prompts when it is ready for further input; the prompt depends on which mode the editor is in. CTRL/O is not echoed.
CTRL/R	This character, typed before an input line is completed, redisplays the entire line. CTRL/R is echoed as ^R.
CTRL/Y	This character immediately gets the attention of the DCL interpreter. You can then type any legal DCL command, such as SHOW or CONTINUE. If the DCL command does not change the SOS image, you can resume SOS by typing the DCL command CONTINUE.
CTRL/C	This character interrupts whatever command is in progress and returns you immediately to Edit mode. Any changes already made by the command (for example, by an Alter or Substitute command) are incorporated into the file. CTRL/C is echoed as ^C.

Figure 7 - VAX Control Characters

If the user types only @GPRIME, the system will prompt for the UMF name, which will be assumed to be a new file in the user's current directory. P2 specifies the user directory. If omitted, GPRIME assumes the current directory. If a directory is specified, brackets must be included and all files will be in that directory. P3 is the name of an old UMF for RESTART or NEW for an initial session, that is, when the user is not going to access any previously defined geometry. P4 can be used to specify an input file, that is, a file previously set up with executive commands, geometric definitions, and other commands that the user could have typed interactively. The default for input is the terminal. P5 can be used to specify a file of data points, such as digitized points, to be used as values in defining geometry. The default name is SPDATA.DAT. P6 is the output file for the BACKUP command in GPRIME and for the PUNCH command in GGEN. The default file name is FEDATA.DAT. All file types are assumed to be DAT if not explicitly specified. Any omitted parameters between specified parameters must be designated with " ". Parameters are separated by a single space. The command procedure can be terminated with any parameter. (Note: Parameters P1 and P3 must not be given the file names UMF, UMF.DAT, or NEW.)

An important difference between systems is apparent immediately. On the VAX, all files are "permanent"; "local" files do not exist. On CDC computers, only the User Master File (UMF) is made permanent by a GPRIME procedure; on the VAX, any files created are in the user's directory until deleted. Although VAX users will never lose their grid and element data on the FEDATA file, they could well find themselves with many unwanted files.

Unlike the CDC user who types all executive commands for opening GPRIME before the computer returns any information, the VAX user will see the word GPRIME printed on the screen immediately after the @GPRIME command. The user then types INIT or RES. GPRIME responds with the time and date. Next the user types INTER,TIME or INTER,STOR. INTER,TIME evokes the time-share mode and is prompted with two periods (..). The user types on the same line as the prompt, instead of below it as with the CDC version. Time-share mode is frequently used on a nongraphics terminal to verify variable names and geometric definitions. Input for time-share mode can be either from an INFILE file or from an interactive terminal.

INTER,STOR will put up the graphics screen outline. It may take a few seconds on a RESTART for this action to occur, as this is the time at which the UMF is being written from disk to computer memory. The user must type END if not using the INFILE option. If the INFILE parameter was specified, GPRIME will first use that information as input and then wait for further interactive input. An END will terminate GPRIME in this mode.

One final note at the executive control level concerns the use of the computer clock. VAX users will not have to Extend Time Limit as do CDC users. Therefore, there is no equivalent to the ETL command and no TIME LEFT-nn SECONDS printout on the graphics screen. This feature was an aid to CDC users to alert them to end a working session the way they wanted to before the CDC system cut them off.

USER-COMPUTER INTERFACE

One major difference between the CDC and VAX versions is the word size: 60 bits per word for the former and 32 bits for the latter. Because GPRIME is highly interactive, this difference in word size has tremendous impact on the user-computer interface. The program code managing this interface has been substantially changed, but user commands differ in relatively few places.

Variable Name Length: Variable names are restricted to a total of 4 characters. Examples: P999; SC45; OT23; WS99

Macro Names: The macro command to build and to execute a macro contains the macro name. On the VAX, this name must be no more than three characters! Example: BUI,MAC; EXEC,MAC

Default: The B-spline fitting function FIT has a default of 32,32 on the VAX version and 16,16 on the CDC version.

CLIP: For the hidden line removal capability, the default of 32 has not been changed but the capability has been enhanced. Values up to CLIP,300 will be useful and the user can try higher values if the model demands.

END: The END command of GPRIME terminates the work session. On the CDC computers all data already resides on disk, so END erases the screen and goes into command language rather quickly. On the VAX the END command prompts GPRIME to write all data to the UMF. The size of this file will determine how quickly the system will respond.

OUTPUT FILE: The output file of grid point and element data is generated in the GGEN module with the PUNCH command. Until further changes are made, the VAX user must first open the FEDATA file with a BACKUP command in GPRIME. All element cards now have CTRS instead of the element type, such as CQUAD2.

WORKSPACE LENGTH: Workspaces on the VAX will hold approximately 500 elements and 500 nodes, compared with about 50 each on the CDC system. However, there is also a trade off here with the field length of the variable names. It is suggested that the VAX GGEN user read carefully the section on DATA MANAGEMENT. Although a large workspace may be useful, the user should also consider screen display and general handling of large quantities of data at one time.

PHILOSOPHY: DISK VS VIRTUAL MEMORY

Two major internal differences between the CDC and VAX computers have impact on data management with GPRIME. The VAX has both virtual memory and an interactive-friendly environment; the CDC has neither. On CDC computers GPRIME uses overlay features and disk storage of data to make the program fit into the core level allocated for interactive use. In both versions, all data, geometric definitions, and plotting parameters exist on a data base, called the User Master File (UMF). On the CDC this data base resides on disk whereas on the VAX it resides in memory, using what we refer to as the "data virtual" routines for data management. These routines take advantage of the virtual memory and keep all data in a very large array. Vax users are not restricted at any time from using the total power of the computer, which is the principal difference in the interactive environments of the two computers.

There is an advantage and a disadvantage in these differences: speed and safety. The advantage is that data residing in memory can be accessed much more quickly than data residing on disk. Therefore, VAX GPRIME is faster than CDC GPRIME. The disadvantage is that on the VAX the user's data is less protected under certain circumstances. In the event of an abnormal GPRIME termination, a system crash, or a user-terminating CTRL/Y (or CTRL/C), the user's entire data base will be lost. One recommendation is that the user keep a second copy of the UMF before a RESTART, thus protecting the previous session's work. We plan to add a module to GPRIME called DVSAVE, which will allow the user to write the data to disk periodically. The intention is that during a very long or complicated working session, the user could periodically

call DVSAVE, providing some measure of protection. Some ERRORS IN GPRIME, such as ILLEGAL DEFINITION, CAUSE THE DATA TO BE WRITTEN TO DISK AUTOMATICALLY. HOWEVER, OTHER ERRORS AS DESCRIBED PREVIOUSLY CAUSE IMMEDIATE TERMINATION. IN THIS EVENT, A FILE NAMED UMF.DAT WILL EXIST. THE FILE WILL BE EMPTY UNLESS SOME GPRIME ERROR WROTE TO IT. THE USER WILL GENERALLY WANT TO DELETE THIS FILE.

DATA MANAGEMENT

Another major difference between the CDC and VAX computers has significant impact on the external, that is, user controlled, data management. Without additional changes to the program, the VAX word length (32 bits) has reduced to four (from CDC's six) the number of characters permitted in the symbolic names of variables which serve as references between the user and the computer. In general the impact of this difference is not felt in the GPRIME module. In the GGEN module most functions such as GENERATE, EDIT, CREATE, and DELETE can be performed without reference to variable names. It is in GGEN's workspace functions, where user access to variables by their names is important, that the program's power is affected. A correction module has been outlined and will be implemented as soon as practicable. Meanwhile the nature of the problem and means to overcome it are described here.

The problem is one of not having a symbolic name field as large as the actual numeric count of nodes and elements. With the VAX virtual memory there is really no limit on the number of nodes and elements that may be handled. At 500 nodes and 500 elements per workspace, with at least 99 workspaces (remember that workspace names may contain alpha characters), the count already exceeds the symbolic name limt of P999 and E999. We offer here alternatives to consecutive numbering that will require some user editing of the output file, as well as some careful work during data generation.

First, after every several workspaces, that is, when the data count on nodes or elements will exceed 999, it is suggested that the next workspace be initialized with RESTORE instead of RENAME. In this way, the numbering of nodes and elements begins again at 1 instead of at the highest number + 1 of the previous workspace. This procedure gives the advantage of having no nodes or elements numbered higher than 999 so that they are callable by any program command. The user should PUNCH the workspaces to the FEDATA file in the order

of creation to aid in bookkeeping and will know what sections of the model are in the workspaces. With a text editor, the user can then simply increment the numbering of nodes and elements by 1000 for every 999 nodes and elements. For example, the first 999 nodes and elements retain their numbering, but the second set could become 1999 to 2999. The user may come up with other helpful schemes either at generation time or in editing the output file.

The imposition of the numbering restriction on the nodes and elements gives rise to a second problem. Most workspaces contain some nodes from a previous workspace, either to indicate continuation from one workspace into another when a bulk generation fills a workspace (this probably will not happen often with the size of VAX WS's) or to indicate a boundary of two adjacent surfaces whose data are stored in separate workspaces. In general, a user enters the next workspace with the GROUP, RENAME, RETAIN sequence described in the section on PARTITIONING THE MODEL. However, RENAME causes the new workspace to resume with consecutive numbering of nodes and elements. In this case, the SET,PARAM,LPID and SET,PARAM,LEID commands can be used to set the numbering of data low enough that all data generated in this new workspace will meet the requirement of having IDs less than 999. Any data carried over from the previous workspace will retain the correct numbering without any duplicates being created.

In summary, the techniques used to avoid the user-computer interface problems include the use of RESTORE or CLEAR, the use of proper RETAIN, SET sequences, and some bookkeeping during generation and in editing the output file. Tremendous power will be available to the VAX user once this problem is corrected, so that such procedures will be unnecessary. At that point the size of the model will be restricted only by the numeric field allowed by GGEN's output file, by the input field allowed by the user's input file to the analyis program, and by the user's own management of large models.

GGEN COMMAND INDEX

ACTIVATE.....activates GPRIME variables in GGEN

ADJUST.....adjusts grid point data, thickness surfaces

ALIGN.....positions menu and drawing on digitiz ing board

CLEAR.....clears workspaces

CREATE,ELEMENTS.....creates elements graphically or by keyboard command

CREATE,NODES.....creates nodes graphically or by key- board command

DEACTIVATE.....deactivates GPRIME variables in GGEN

DELETE.....deletes GGEN variables

DISPLAY.....displays requested items on screen

DUMP.....copies contents of workspace to printer, for system debugging

EDIT.....activates "menu" for interactive modeling

END.....returns to GPRIME, with saved workspace

GENERATE.....generates data in bulk

GGEN.....enters the GGEN system from GPRIME

GROUP.....stores data into groups

GPRIME.....stores GGEN groups and points in GPRIME's UMF

HELP.....obtains on-line information for using GGEN

PLOT.....sets parameters for screen display

PROCESS.....processes GPRIME functions while remaining in GGEN

PUNCH.....puts finite element data on output file

PURGE.....purges permanently selected data

QUIT.....returns to GPRIME without data save

RENAME.....gives new name to workspace, or initializes new WS

RESTORE.....makes a workspace active

RETAIN.....retains or deletes workspace data

SAVE.....writes workspace data to disk, GPRIME's UMF

SET,DUPLICATE.....marks data as duplicates in other workspaces

SET,PARAM.....controls data numbering, tolerances

SET,SPACING.....sets mesh sizes

STATUS.....obtains on-line data parameters

WSPURGE.....permanently deletes workspaces

ZZZ.....executes experimental modules

ACKNOWLEDGMENTS

Many people have contributed to the development of the GGEN interactive data generator. In particular the authors would like to thank Michael E. Golden for his role in developing the interfaces between the GPRIME and GGEN programs, and for initiating the CDC to VAX conversion of the total system. Others who have made significant contributions include Suzanne Wybraniec in her role as programmer and program librarian for the project and Dr. Letitia Korbly who developed the triangular meshing algorithm. The authors also appreciate the substantial efforts of Mary Beth Marquardt in completing the CDC to VAX conversion of the GPRIME-GGEN system. Finally, early users of GGEN who have made many helpful comments include Ernest Brooks, Melvyn Marcus, and Antonio Quezon.

The authors also wish to thank Reginald Mitchell of NASA-Goddard for the use of the DEC VAX 11/780 computer and for his help with the VAX and the VMS operating system, as well as many other details. Gary Jones of NASA-Goddard also helped with solving conversion difficulties and with testing the VAX version. Others who have contributed are Richard van Eseltine (who did the RATFOR FORTRAN preprocessor); Dan Allen (who helped with VMS questions and with control character CTRL/C for what will be our later implementation of DVSAVE); and Gladys Davis (who served as courier between NASA and DTNSRDC).

REFERENCES

1. McKee, J.M. et al., "GPRIME: A Geometric Language for Finite Element Modeling Program Manual," DTNSRDC Report 82-062 (Sep 1982).

2. Kazden, R.J., "SOLIDGEN: A Solid Finite Element Data Generator User's Manual," DTNSRDC Report (in publication).

3. The NASTRAN User's Manual, NASA SP-222(05), National Aeronautics and Space Administration, Scientific and Technical Information Office, Washington, D.C., (Dec 1978).

4. VAX-11 Text Editing Reference Manual, AA-D029A-TE, Digital Equipment Corporation, Maynard, Massachusetts (Aug 1978).

INITIAL DISTRIBUTION

Copies		Copies	
5	ONR	2	NCSC
	1 ONR 411		1 751/P. Bishop
	1 ONR 411MA		1 Tech Lib
	1 ONR 432		
	1 ONR 437	2	NOSC/San Diego
	1 ONR 474		1 7132/L. McLeary
			1 Tech Lib
2	USA PICATINNY ARSENAL		
	1 B. Nagel	1	NPRDC
	1 A. Tese		1 P311/D. Rahilly
1	USA BRL/Aberdeen	5	NBS
	1 P. Deitz		D. Wallace (Code 644)
			Technology Bldg. B266
1	CNO		
	1 OP 901M/M. Golden	3	NSWC/White Oak
			1 K22/R.J. Edwards
1	DNL		1 E22/E. Peizer
			1 Tech Lib
5	NRL		
	1 246/R. Perlut	2	NSWC/Dahlgren
	1 2310/R. Shimkus		1 K21/C. Blackman
	1 5840/R. Skop		1 Tech Lib
	1 7732/L. Turner		
	1 5836/W. Webbon	2	NUSC/New London
			1 44/A. Carlson
2	USNA		1 Tech Lib
	1 Dept. Math		
	1 Tech Lib	2	NUSC/Newport
			1 3701/C. Curtis
2	NADC		1 Tech Lib
	1 501/J. Heap		
	1 Tech Lib	1	NCEL/Port Hueneme
			1 Code L51/F. Johnson
1	NATC/Patuxent		
	1 Don Louieos	2	NWC
			1 32H2/J. Serpanos
3	NAVPGSCOL/Lib		1 Tech Lib
	1 G. Cantin		
	1 A. Shoenstadt	1	NAVAIR
	1 Tech Lib		1 1154/G. Hand
1	NAVWARCOL	3	NAVMAT
			1 MAT 071
1	ROTC, MIT		1 MAT 0714
			1 MAT 064

Copies	
10	NAVSEA
	1 SEA 03A
	1 SEA 03R24
	1 SEA 55Y
	1 SEA 32113/J. Claffey
	1 SEA 32133/W. Sandburg
	1 SEA 05R15/H. Vanderveldt
	1 SEA 03R3/P. Anklowitz
	1 SEA 03R2/J. Gagorik
	1 SEA 05R24/J. Sejd
	1 SEA 32323/R. McCarthy
1	NAVSHIPYD BREM/Lib
1	NAVSHIPYD CHASN/Lib
1	NAVSHIPYD MARE /Lib
1	NAVSHIPYD NORVA/Lib
1	NAVSHIPYD PEARL/Lib
1	NAVSHIPYD PHILA/Lib
1	NAVSHIPYD PTSMH/Lib
12	DTIC
16	AFWAL/WPAFB, OH 45433
	12 FIBRA/B. Groomes
	1 FIBRA/V. Tishler
	1 FIBE/D. Paul
	1 J. Johnson
	1 J. Folck
2	AFLC/Kelly AFB
	1 J.L. Cotnam
	1 M. Leo
1	NASA Headquarters
	1 RWS/A.K. Amos
8	NASA Goddard SFC
	1 J. Mason
	1 R. Mitchell
	1 C.E. Jackson, Jr.
	1 L. Purves
	3 G. Jones
	1 Tech Lib

Copies	
6	NASA Langley Research Center
	1 R. Fulton
	1 J. Rogers
	1 P. Manos
	1 G.L. Giles
	1 J.C. Robinson
	1 Tech Lib
2	NASA Lewis Research Center
	1 MS 886-1/H.C. Kao
	1 Tech Lib
2	NASA Flight Research Center
	1 D. Hedgley
	1 Tech Lib
2	NASA Marshall SFC
	1 ED22/R. McComas
	1 Tech Lib
3	NASA Ames Research Center
	1 Mladen Chargin
	1 Thomas Lasinski
	1 Tech Lib
1	Sandia National Laboratories
	1 5523/R. Koteras
1	Mr. Edwin N. Nilson, Manager Pratt & Whitney Aircraft Group Tech. Mgmt. & Data Systems 400 Main Street East Hartford, CT 06108
1	Dr. J.K. Lee Dept. of Engineering Mech. Ohio State University 155 West Woodruff Avenue Columbus, OH 43201
1	Mr. Brian J. McCartin-EB2C Pratt & Whitney Aircraft Group 400 Main Street East Hartford, CT 06108
1	Dr. Jeffrey Morgan, Vice Pres. Universal Analytics, Inc. 7740 West Manchester Blvd. Playa Del Rey, CA 90291

Copies

1 Mr. David Oswald
CDM Division
National Computer Systems
4401 West 76th Street
Minneapolis, MN 55435

1 R.P. Schmitz
Sperry Support Service
Huntsville Engineering Operations
1112 Church Street
Huntsville, AL 35801

1 Dr. David Bushnell
Lockheed Missiles & Space Co., Inc.
Orgn. 52-33, Bldg. 205
3251 Hanover Street
Palo Alto, CA 94304

1 Dr. F. Hubert Ho
The B.F. Goodrich Co.
Research and Development
Brecksville, OH 44141

1 Dr. Joe Glouderman
MacNeal-Schwendler Corp.
7442 N. Figureoa Street
Los Angeles, CA 90041

1 Mr. D.J. Tree
Airesearch Manufacturing Co. of Arizona
111 South 34th Street
P.O. Box 5217
Phoenix, AZ 85010

1 Dr. Hussein A. Kamel
Department of Aerospace and Mechanical Engineering
University of Arizona
Tucson, AZ 85721

1 Dr. Albert L. Klosterman
Vice President/Technical Dir.
Structural Dynamics Research Corporation
2000 Eastman Drive
Milford, OH 45150

Copies

1 Mr. Sam Sampath
Transp. & Structure Dept.
Battelle Columbus Labs.
505 King Avenue
Columbus, OH 43201

1 Dr. Lewis E. Hulbert
Transp. & Structure Dept.
Battelle Columbus Labs.
505 King Avenue
Columbus, OH 43201

1 Dr. George Allen
Consultant, CAD/CAM
McDonnell Douglas Automation Company
22500 S. Avalon Blvd.
Carson, CA 90745

1 Dr. Vangala S. Reddy
Babcox and Wilcox
20 S. Van Buren Avenue
Barberton, OH 44203

1 Mike Bailey
Mechanical Engineering Bldg.
Purdue University
West Lafayette, IN 47907

1 Z. Gabrijel
Gas Dynamics Laboratories
Aerospace Engineering Bldg.
The University of Michigan
Ann Arbor, MI 48109

1 Ronald Winter
Bldg. 150B
Tennessee Eastman Co.
Kingsport, TN 37662

1 Mr. C.J. Parekh
Airesearch Manufacturing Co. of California
2525 West 190th Street
Torrence, CA 90509

1 Dr. Jack C. Wiley
Deere & Company
Tecnnical Center
Moline, IL 61265

Copies

1 Don Pan
Bolt, Beranek, and Newman
Union Station
New London, CT 06320

1 Steve Roggenkamp
General Electric Co.
Aircraft Engineering Group
Mail Drop K190
Cincinnati, OH 45215

1 Mr. S.W. Park
Control Data Corporation
4201 Lexington Ave. North
Arden Hills, MN 55112

1 Mr. Thomas Butler
932 Beaver Branch Circle
Towson, MD 21204

1 H.D. Seamons
MARC Analysis Research Corp.
260 Sheridan
Palo Alto, CA 94306

1 Mr. M.J. Roche
(B13-35)
Grumman Aerospace Corp.
Bethpage, NY 11714

1 Thomas P. Bligh
Associate Professor of Mechanical Engineering
Mass. Institute of Technology
Cambridge, MA 02139

1 Rudolph Brown
Mail Stop 434
Westinghouse Electric Co.
Systems Development Division
P.O. Box 746
Baltimore, MD 21203

1 R. Elward
Air Products & Chemicals
P.O. Box 538
Allentown, PA 18105

Copies

1 Mr. Stephen M. Hollister
Mail Stop C62
General Dynamics Corp.
Electric Boat Division
Eastern Point Road
Groton, CT 06340

1 Dr. Bharat K. Soni
Computational Fluid Dynamics Group, ED6
AVERDRUP Technology, Inc.
AEDC Group, Mail Stop 500
Arnold Air Force Station,
Tennessee 37389

1 Dr. Richard Zarda
Martin Marietta Aerospace
Mail Point 275
Orlando Division
P. O. Box 5837
Orlando, FLA 32805

1 Ms. Ann Shadis
Tactical Equipment Corp.
39 East Forest Ave.
Shrewsbury, PA 17361

1 Dr. L.H. Seitleman
KBA2C/165-09
400 Main Street
East Hartford. Conn. 06108

1 L.B. Stripling
President and Engineering Consultant
INTRATEC, Inc.
573 Pine Street

1 Dr. Richard L. Citerley
Anamet Laboratories, Inc.
100 Industrial Way
San Carlos, CA 94070

1 Donald Scheiber
Magnavox Company
1313 Production Road
Fort Wayne, IN 46808

Copies		
1	Dr. Oliver K.L. Wang SKF Industries P.O. Box 515 1100 First Avenue King of Prussia, PA 19406	
1	Mr. Alfred Vachris RAVES Project Leader Grumman Aerospace Corp. B17-35 South Oyster Bay Road Bethpage, NY 11714	
1	Robert Jackson Mail Drop K101, I-75 General Electric Co. Evendale, OH 45215	
1	John S. Ma Structural Engineering Bldg. Office of Nuclear Reactor Regulation Nuclear Regulatory Commission Washington, D.C. 20555	

CENTER DISTRIBUTION

Copies	Code	Name
1	012.4	R. Stevens
1	11	W.M. Ellsworth
1	1182	Z.G. Wachnick
1	15	W.B. Morgan
1	1542	D.F. Thrasher
1	1568	L. Motter
1	16	H. Chaplin
1	17	W.W. Murray
1	1702	J. Corrado
1	1720.2	K. Hom
1	1720.3	R.F. Jones
1	1720.6	R.D. Rockwell
1	1730	A.B. Stavovy
1	1730.5	J.C. Adamchak
2	1750.2	B. Whang P. Roth
1	18	G.H. Gleissner
1	1802.1	H.J. Lugt
1	1805	E.H. Cuthill
2	1809.3	D. Harris
1	1820	A. Camara
1	1824	S. Berkowitz
1	1840	J.W. Schot
2	1843	H.J. Haussling M.B. Marquardt
6	1844	S.K. Dhir R. Kazden P. Matula M. Marcus A. Quezon S. Wybraniec
50	1844	M. Hurwitz
100	1844	J.M. McKee
1	185	T. Corin
1	187	M. Zubkoff
1	189	G. Gray
1	1892.1	J. Strickland
1	1892.2	D. Sommer
1	19	M.M. Sevik
1	1966	J. Casper
1	27	W.C. Deitz
1	272.1	H.N. Urbach
1	2723	P. Hatchard
1	28	J.R. Belt
1	2822	W. Palko
2	2832	J. Dray T. Daugherty
1	29	F.H. Kendall, Jr.
10	5211.1	Reports Distribution
1 & 1m	522.1	Unclassified Lib (C)
	522.2	Unclassified Lib (A)
1	93	L. Marsh


DATE
FILMED
5-8